

**GENETIC STUDIES FOR AQUACULTURE AND  
STOCK-ENHANCEMENT OF RED DRUM (*Sciaenops ocellatus*)**

A Thesis

by

LIANG MA

Submitted to the Office of Graduate Students of  
Texas A&M University  
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2006

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee,	John R. Gold
Committee Members,	Delbert M. Gatlin III
	J. Spencer Johnston
Head of Department,	Robert D. Brown

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## ABSTRACT

Genetic Studies for Aquaculture and Stock-enhancement of

Red Drum (*Sciaenops ocellatus*). (May 2006)

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Chair of Advisory Committee: Dr. John R. Gold

Hypervariable, nuclear-encoded microsatellites were used to (i) estimate genetic effective size ( $N_e$ ) of red drum spawning over a two-week period in nine brood tanks at a TPWD hatchery; (ii) estimate heritability of early-larval growth and of growth rate and cold tolerance of juveniles; and (iii) test Mendelian segregation and independent assortment of 31 nuclear-encoded microsatellites. Assuming all tanks contributed equally to an offspring population, the maximum (expected) and observed  $N_e$  over the nine brood tanks was 43.2 and 27.0, respectively. The estimate of  $N_e$  based on observed variation in family size was 19.4. Simulations indicated that over a limited time period the simplest approach to maximizing  $N_e$  for a release population would be to utilize equal numbers of progeny from each brood tank. A family (genetic) effect was found to contribute significantly to the variance in early larval growth, juvenile growth rate, and cold tolerance. Estimates of narrow-sense heritability for these three traits were  $0.07 \pm 0.03$ ,  $0.52 \pm 0.21$  and  $0.20 \pm 0.10$  (two growth intervals measured), and  $0.30 \pm 0.11$ , respectively, under the genetic models employed. The relatively low estimate of heritability for early larval growth suggests that genetic improvement for this trait likely would be slow. The heritability estimates for juvenile growth rate and cold tolerance, alternatively, suggest that genetic selection for these traits could be effective.

Segregation at all 31 microsatellites fit Mendelian expectations for autosomal loci; a null allele was inferred at two of the microsatellites. Results from pairwise tests of independent assortment demonstrated that 20 of the 31 microsatellites could be placed into seven linkage groups. Additional linkage groups inferred from a prior study increased the number of inferred linkage groups in red drum to nine, with a range of two – five (avg. = 2.78) microsatellites in each linkage group. The remaining 11 microsatellites tested in this study assorted independently from all other microsatellites, suggesting the possibility of 11 additional linkage groups.

## **DEDICATION**

To my parents and my fiancée

## **ACKNOWLEDGEMENTS**

I would like to thank my committee chair, Dr. Gold, and my committee members, Dr. Gatlin and Dr. Johnston, for their guidance and support throughout the course of this research.

Thanks also to my friends and colleagues and the department faculty and staff for making my time at Texas A&M University a great experience. I also want to extend my gratitude to the Texas Parks and Wildlife Department (TPWD) which provided the experimental materials, and Aquacultural Research and Teaching Facility (ARTF) at Texas A&M University where the experiments to assess heritability of growth rate and cold tolerance were conducted.

Finally, thanks to my mother and father for their encouragement and to my fiancée for her patience and love.

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## 1. INTRODUCTION

*Sciaenops ocellatus* (red drum) is an economically important marine fish species in the northern Gulf of Mexico, especially along the coast of Texas where the total economic impact of the red drum recreational fishery is estimated to exceed \$1 billion annually (R. Riechers, Texas Parks and Wildlife Department, pers. comm. to J. R. Gold). Dramatic declines in population numbers of red drum in Texas waters during the 1970s and 1980s led to the prohibition of commercial sale of 'wild' red drum and to the implementation of harvest restrictions (Matlock, 1990). In 1982, the Texas Parks and Wildlife Department (TPWD) began a red drum stock-enhancement program to supplement the recreational fishery in state waters (McEachron et al., 1995). Today, the program has an annual operating budget of ~\$1.3 million (R. Vega, pers. comm. to J. R. Gold), and over 30 million hatchery-produced fingerlings are released annually into various Texas bays and estuaries (Vega et al., 2003).

In this study, hypervariable DNA markers (microsatellites) are employed to address issues related to the TPWD stock-enhancement program and to red drum aquaculture in general. The primary issues are: (i) the genetic effective size of the breeding population at TPWD hatcheries; and (ii) the genetic basis (broad-sense heritability) of early-stage larval growth, growth rate of juveniles, and cold tolerance. A secondary issue studied is the Mendelian inheritance (segregation and assortment) of 31 nuclear-encoded microsatellites.

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This thesis follows the style of Aquaculture.

### *1.1. Genetic effective population size*

Hatchery-reared fish used in stock-enhancement programs are often produced by a small number of breeders as compared to the hypothesized number of breeders in natural populations (Ryman and Laikre, 1991). Consequently, hatchery broodfish may not possess the full range of genetic variability found in wild stocks. In addition, a small number of broodfish may contribute disproportionately to the juvenile pool, leading to a significant increase in the variance in family size. This can lead to both genetically compromised fish being stocked into the 'wild' and to a reduction in the genetic effective size of the 'wild' population (Ryman and Laikre, 1991; Utter, 1998). The genetic effective size of a population ( $N_e$ ) is the size of an ideal population that has the same properties with respect to genetic drift or inbreeding as the actual population (Yokota et al., 2003). A significant reduction in genetic effective population size may thus result in inbreeding and accumulation of deleterious genotypes (Frankham, 1995; Higgins and Lynch, 2001), leading potentially to a reduced capacity of 'stocked' fish to respond to changing or novel environmental pressures. Supplementing a 'wild' population with hatchery-raised fish also may reduce genetic effective size of the 'wild' population, if the 'stocked' fish reproduce and contribute significantly to subsequent 'wild' generations (Ryman and Laikre, 1991). This is known as the 'hatchery effect' or the 'Ryman-Laikre effect.' These issues are of concern to conservation and management of a fishery resource, particularly if the resource is being enhanced via supplementation with hatchery-raised fish (Ryman and Laikre, 1991).

The stock-enhancement program used by TPWD has integrated several practices to

partially alleviate or mitigate these concerns. These practices include randomly mating 5-6 broodfish (minimum of three females) in each spawning tank, alternating females and males in different spawning tanks across years, replacing at least 25% of the broodfish (both sexes) annually, and not maintaining any broodfish in the program for more than four years (McEachron et al., 1995). In order to evaluate the efficiency of current practices in mitigating potential problems associated with small effective population size of broodfish, the actual effective size based on offspring produced from 13 separate spawning events that occurred in a TPWD hatchery during the spring of 2002 was estimated. In particular, potential reduction in effective population size due to unequal family size was examined by comparing the actual estimated effective size with the expected effective size assuming all breeders present in the spawning tanks contributed equally to offspring.

### *1.2. Heritability of quantitative traits*

The genetic basis of many important traits (e.g., growth rate, temperature tolerance) of fish in aquaculture is assumed but not frequently demonstrated. Most of these ‘quantitative’ traits exhibit continuous variation (Bennett and Beitinger, 1997; Choe and Yamazaki, 1998), due in part to the additive effects of multiple genes on phenotype. The model for quantitative traits is that the phenotypic variance ( $V_P$ ) observed for the trait is the sum of the variance of genetic effects ( $V_G$ ), the variance of environmental effects ( $V_E$ ), and the interaction that exists between the two (Tave, 1993). The proportion of the phenotypic variation due to the genetic influence is termed ‘broad-sense’ heritability ( $h^2 = V_G/V_P$ ) and is of interest to a breeding program relative to

improving productivity (Tave, 1993). The subcomponents of genetic variance are the additive genetic variance ( $V_a$ ), the dominance genetic variance ( $V_d$ ), and the epistatic genetic variance ( $V_i$ ) (Tave, 1993). Only the additive genetic variance ( $V_a$ ) reflects the proportion of genetic effects that are transmitted from parent to offspring in a predictable and reliable manner (Tave, 1993), and as a consequence, serves as the basis for artificial selection to improve the average performance of offspring (Lutz, 2001). The proportion  $V_a/V_P$  is termed 'narrow-sense' heritability (Wright, 1951).

Interest in the culture of red drum began in the 1970s (Gatlin, 2000) and research on nutrition and husbandry of the species has been intensive (Craig et al., 1995; Gatlin, 2002). However, very little research has been done on the genetic basis or heritability of traits important to red drum aquaculture. Studies in other fish species used in aquaculture (Murata et al., 1996; Koedprang et al., 2000; Henryon et al., 2002) have generally revealed heritability estimates for growth rate, assessed as body weight and as body length at a given age, in the range 0.10 – 0.40 and 0.10 – 0.50, respectively. Such high heritability values lead to the prediction that selective breeding for these traits should generate a significant response. Because size of larval fish is a critical determinant of recruitment success and subsequent year-class strength (Leggett and Deblois, 1994; Westerman and Holt, 1994), faster growing fish could reach the critical size required for survival in the wild sooner than more slowly growing fish. Higher *per capita* survival of stocked fish in the 'wild' might minimize expenses in physical resources (ponds, fertilizer, etc.) and personnel needed for a stock-enhancement program. In this study, narrow-sense heritability of larval growth and of juvenile growth rate in red



drum was estimated in order to evaluate potential for selection for fast growth in hatchery raised red drum.

The narrow-sense heritability of cold tolerance in red drum also was investigated. Briefly, red drum are notoriously sensitive to cold and do not survive temperatures below  $\sim 7.0^{\circ}\text{C}$  (Procarione, 1986; D. M. Gatlin, pers. comm.). This cold temperature sensitivity can cause high mortality during the winter if red drum are grown in outdoor facilities; and during the late 1980's and early 1990's, catastrophic losses at red drum culture operations were attributed to sudden or severe freezing temperatures (Lutz, 1999). Tentative 'facility' solutions to this cold sensitivity have included winter nursery facilities, in-pond thermal refuges, and indoor over-wintering facilities (Lutz, 1999).

Spawning of the TPWD red drum stock-enhancement program occurs from spring to early fall (April - September) and differs from the natural spawning season which occurs during late summer to late fall (August - November) (McEachron et al., 1995). Part of the reason for altering spawning time was to avoid the mortality that might occur during winter when larvae are placed in the relatively shallow, outdoor grow-out ponds used at TPWD facilities. More cold-resistant fish might therefore allow TPWD to mimic natural spawning and permit stocking to occur during most or all of a year.

Cold tolerance has been studied in red drum and in other species (Procarione, 1986; Craig et al., 1995; Lankford and Targett, 2001; Sun and Liang, 2004). The studies in red drum investigated both thermal tolerance (Procarione 1986) and the relationship between cold tolerance and nutrition (Craig et al., 1995). The genetic basis of cold tolerance and the relationship between cold tolerance and other traits in a tilapia hybrid

was studied by Cnaani et al. (2003, 2004) who found evidence of both an additive-genetic effect and a dominance effect relative to cold tolerance. The narrow-sense heritability of cold tolerance estimated for red drum will be used to assess whether selective breeding for cold tolerance could be implemented as a means to initiate stock-enhancement throughout the year.

### *1.3. Genetic markers*

Recovering pedigree information in quantitative-genetic experiments involving fish species classically requires that offspring from different families be reared in separate rearing units (tanks) until they are large enough to be physically tagged. Testing large numbers of families (i.e. 100 or more) as required for genetic parameters estimation would therefore require considerably large numbers of rearing tanks thus resulting in prohibitive costs (Norris et al., 2000). These costs are also multiplied by a factor of at least two when family rearing tanks are replicated in order to avoid confusion of family (genetic) effect with early common environmental effect (i.e., tank effect) in the estimation of genetic values. Hypervariable DNA markers such as microsatellites solve this problem by allowing offspring from various parental crosses to be reared in the same tank and (re)assigned to their parents, even in large, multi-parental crosses (Norris et al., 2000; VanDeputte, 2003). Herbinger et al. (1995), for example, obtained pedigrees (i.e., identified full-sib and half-sib relationships) in a mix of farmed populations of rainbow trout and were able to assign over 91% of the offspring back to one or two of 100 possible crosses on the basis of genotypes at four microsatellites.

Briefly, microsatellites consist of a large number of short, tandem arrays of

nucleotides that are more or less evenly distributed throughout the genome (Edwards et al., 1991). Allelic variation in microsatellites is usually assayed via polymerase-chain-reaction (PCR) amplification, where designed PCR primers bind to unique DNA sequences on either side of the repeat unit array. Microsatellite alleles are identified by size differences (due to the variable number of repeats) as visualized on denaturing polyacrylamide gels. Microsatellites are codominantly inherited and are assumed to follow Mendelian laws (Jarne and Lagoda, 1996).

A suite of microsatellites developed for red drum by Turner et al. (1998), O'Malley et al. (2003), and Saillant et al. (2004) was employed in this study to assess parentage relative to estimating both genetic effective size and heritability of growth rate and cold tolerance. In addition, 31 of the red drum microsatellites were tested for Mendelian segregation and assortment. Demonstration of Mendelian inheritance for these microsatellites will facilitate their use as 'anchor' loci (Silver et al., 1991) in future studies to genetically map the red drum genome.

## **2. EXPERIMENTAL OBJECTIVES OF THE STUDY**

There are three experimental objectives of the current study. They are: (i) estimate the genetic effective size of the red drum broodfish involved in 13 spawning events occurring at a TPWD hatchery in the spring of 2002 and compare the estimate of genetic effective size with that expected, under optimal conditions, based on the total number of broodfish employed; (ii) estimate the narrow-sense heritability ( $h^2$ ) of early-larval growth, growth rate of juveniles, and cold tolerance of red drum; and (iii) test Mendelian inheritance of 31 microsatellites developed from a red drum genomic library.

### 3. MATERIALS AND METHODS

#### 3.1. *Fish*

A total of 45 adult red drum broodfish (27 females and 18 males), maintained at the (TPWD) CCA/CPL facility in Flour Bluff, Texas, was used in the project. The broodfish were obtained by TPWD personnel from the 'wild' red drum population offshore of the south Texas coast. The broodfish were divided into nine different spawning tanks, each putatively containing two males and three females. In 2002, a total of 125 offspring were randomly sampled from each of 13 separate spawning events in order to (i) estimate genetic effective size, (ii) estimate heritability of early-larval growth, and (iii) test patterns of Mendelian inheritance of microsatellites. In 2003, a total of 450 offspring were obtained from 10 separate spawning events (45 fish from each of the 10 spawns) and used in experiments to estimate heritability of juvenile growth rate and cold tolerance. TPWD personnel at the CCA/CPL facility carried out all fish husbandry, including spawning and larval rearing, during the spring of each year. In 2002, the offspring were sampled at the CCA/CPL facility; in 2003, the offspring were transferred by TPWD personnel to the Aquacultural Research and Teaching Facility (ARTF) at Texas A&M University where the experiments to assess heritability of growth rate and cold tolerance were conducted.

#### 3.2. *Genomic DNA extraction*

Genomic DNA from all brood fish samples was extracted from caudal fin tissue via standard phenol-chloroform procedures, as described in Gold and Richardson (1991).

Genomic DNA from all experimental progeny was also extracted from caudal fin tissue but using an alkaline-lysis method (Saillant et al., 2002). A small piece ( $\approx 2 \text{ mm}^3$ ) of fin from each individual was digested for two hours at  $65^\circ\text{C}$  in  $50 \text{ }\mu\text{l}$  of a sodium hydroxide solution (200 mM). Final pH of the solution was adjusted to 8 by adding  $50 \text{ }\mu\text{l}$  Tris-HCl (200 mM, pH 8.0).

### 3.3. *Microsatellite genotyping*

Microsatellite genotypes were obtained via PCR amplification. PCR products were loaded on 5% Long Ranger single pack gels and electrophoresed on an ABI PRISM 377XL DNA <sup>®</sup> automatic sequencer (Applied Biosystems). One of each pair of PCR primers (Appendix 1) was fluorescently labeled with one fluorescent dye of set D (6-Fam, Hex or Ned). Microsatellites *Soc* 19, *Soc* 85, *Soc* 402, and *Soc* 428 were used for parental assignment in the experiments to estimate effective population size and heritability of early larval growth, juvenile growth rate, and cold tolerance. PCR reactions for parental assignment were performed in  $10\text{-}\mu\text{l}$  volumes containing  $1 \text{ }\mu\text{l}$  (100 ng) of genomic DNA,  $1 \text{ }\mu\text{l}$  of  $10\times$  reaction buffer [500 mM KCl, 200 mM Tris-HCl (pH 8.4)], 1.5 mM  $\text{MgCl}_2$ , 2.5 mM of each DNTP, 5 pM of each primer, 0.5 units of *Taq* DNA polymerase (Gibco BRL). Thermal cycling was carried out as follows: initial denaturation at  $95^\circ\text{C}$  for 5 min, followed by 35 cycles consisting of 45 sec denaturation at  $95^\circ\text{C}$ , 45 sec annealing at the optimized annealing temperature, 1 min extension at  $72^\circ\text{C}$ , with a final extension of 10 min at  $72^\circ\text{C}$ . PCR amplification protocols followed those outlined in Saillant et al. (2004). Six multiplex PCRs (Appendix 2), based on the work of Renshaw et al. (2005), were used for the experiments to test Mendelian

segregation and independent assortment. Multiplex PCR reactions across all panels were performed in 10- $\mu$ l volumes containing 1.5  $\mu$ l (50 ng) of genomic DNA, 1  $\mu$ l of 10 $\times$  reaction buffer [500 mM KCl, 200 mM Tris - HCl (pH 8.4)], 2 mM MgCl<sub>2</sub>, 2.5 mM of each dNTP, different sets of primers with different concentrations of each (Appendix 2), and 0.75 units of *Taq* DNA polymerase (Gibco BRL). Touchdown protocols for multiplex PCR amplification followed those outlined in Renshaw et al. (2005). The Touchdown I protocol involved initial denaturation at 95°C for 3 min, followed by 12 cycles of 30 sec denaturation at 95°C, 1 min at annealing temperature (decreased 0.5°C per cycle), 4 min extension at 72°C, and another 30 cycles of 30 sec denaturation at 95°C, 1 min annealing at 'bottom temperature', 4 min extension at 72°C, and final extension of 10 min at 72°C. The Touchdown II protocol contained (i) initial denaturation at 95°C for 3 min, followed by seven cycles of 30 sec denaturation at 95°C, 1 min annealing at optimal temperature one, and 4 min extension at 72°C, (ii) another seven cycles of 30 sec denaturation at 95°C, 1 min annealing at optimal temperature two, and 4 min extension at 72°C; and (iii) 28 cycles of 30 sec denaturation at 95°C, 1 min annealing at optimal temperature three and 4 min extension at 72°C. Final extension was at 72°C for 10 min. Annealing temperatures for both Touchdown I and II protocols are given in Appendix 2. All gels were analyzed using GENESCAN ANALYSIS 2.1 (ABI, 1996a); allele-calling was performed with GENOTYPER® software, version 2.5 (ABI, 1996b). Genotypes at each microsatellite for each individual were scored and entered into a database.

### 3.4. *Estimating genetic effective population size ( $N_e$ )*

The genetic effective population size ( $N_e$ ) of the broodstock used in the experiment represents the effective number of broodfish that contributed to progeny that would be released for stock enhancement.  $N_e$  is influenced by the number of mating combinations per brood tank, variation in family size among mating combinations within each brood tank, and by variation in the number of progeny from each brood tank released into the wild. Three different estimators of  $N_e$  were utilized in order to account for these factors and quantify their effects on the  $N_e$  resulting from the experimental procedure. The first considers the number of dams and sires that produce offspring in each brood tank and assumes that they contribute equally to offspring production. This value of  $N_e$  was estimated according to...

$$N_e = \frac{4N_s N_d}{(N_s + N_d)} \quad \text{Equation 1}$$

where  $N_e$  is the genetic effective population size and  $N_s$  and  $N_d$  represent the average number of sires and dams per brood tank, respectively. The second estimator of  $N_e$  was based on the actual number of offspring (family size) produced from each dam x sire combination and thus accounts for unequal contributions of the parents to offspring. This value of ( $N_e$ ) was estimated after Chevassus (1989) according to...

$$N_e = \frac{4(N - 2)}{(K_s + \frac{V_s}{K_s}) + (K_d + \frac{V_d}{K_d}) - 2} \quad \text{Equation 2}$$

where  $N_e$  is the genetic effective population size,  $N$  is the total number of offspring,  $K_s$



and  $K_d$  represent the average number of offspring per sire and per dam, respectively, and  $V_s$  and  $V_d$  represent the variance in the number of offspring per sire and per dam, respectively. The third estimator of  $N_e$  was based on the number of offspring that could be released into the ‘wild’ from each brood tank and thus accounts for unequal contribution of each brood tank. This value of  $N_e$  was estimated after Ryman and Laikre (1991) according to...

$$N_e = \frac{1}{\sum_{i=1}^k \frac{x_i^2}{N_{ei}}} \quad \text{Equation 3}$$

where  $N_e$  is the overall genetic effective population size,  $x_i$  is the proportion of the  $i^{\text{th}}$  subpopulation’s contribution to the final population, and  $N_{ei}$  is the genetic effective population size of the  $i^{\text{th}}$  subpopulation.

### 3.5. *Heritability of early-larval growth*

From 29 May to 8 June (2002), a total of 125 offspring was randomly sampled at 41-57 days post spawning from each of 13 separate spawns that occurred between 1- 23 April. Weight and length of each fish were measured after sampling. The phenotypic correlation between weight and length was estimated using Pearson’s linear correlation coefficient (Zar, 1984). Because of the strong correlation ( $0.97 \pm 0.01$ ) between weight and length, only weight data were used to estimate genetic parameters of early larval growth. Significance of the effects on phenotype (early larval growth) involved in the experimental design, i.e., spawning-event effect and family (genetic) effect (nested within spawn) was tested by means of ANOVA carried out using the PROC GLM

procedure of SAS 8.2 (SAS, 2001). Type IV sums-of squares was employed (SAS, 2001), thus allowing testing of effects in the presence of missing sire x dam combinations. Variance components, and their standard errors, associated with each effect accounted for in the selected model (below) were estimated by the Restricted Maximum Likelihood (REML) method as implemented in VCE-4.0 (Variance Components Estimation 4.0) (Groeneveld and Kovac, 1990). The model selected was...

$$y_{ijk} = \mu + sp_i + f_j(SP) + e_{ijk} \quad \text{Equation 4}$$

where  $\mu$  is the overall mean,  $sp$  is the spawning-event effect,  $f_j(SP)$  is the family (genetic) effect (nested within spawn), and  $e_{ijk}$  is the random error. Heritability of early-larval growth was estimated by partitioning the phenotypic variance into components due to the two effects involved in the experimental design. Heritability (narrow-sense) was estimated as twice the ratio of the genetic (family) component of variance divided by the total phenotypic variance (spawning-event plus family {nested within spawn} plus residual) after Becker (1984).

### 3.6. *Heritability of juvenile growth rate*

A total of 450 offspring from 10 separate spawning events in 2003 (45 fish per spawn) was PIT-tagged upon arrival to the ARTF and placed randomly into three, 600-liter experimental tanks connected to a recirculating water system. Dissolved oxygen, salinity, temperature, and amount of feed provided each morning to the experimental tanks were monitored daily. Weight and length of each individual were

recorded on 3 October 2003 (148 days post-spawning), 13 November 2003 (189 days post-spawning) and 2 December 2003 (208 days post-spawning). Raw data were sorted and input files for SAS prepared in Microsoft Excel. The phenotypic correlation between weight and length at each latter two measurement times (189 days post-spawning and 208 days post-spawning) was estimated using Pearson's linear correlation coefficient (Zar, 1984). Because of the strong correlations ( $0.95 \pm 0.02$  at 189 days post-spawning and  $0.96 \pm 0.02$  at 208 days post-spawning) between weight and length, only weight data were used to estimate genetic parameters of juvenile growth rate. Instantaneous exponential growth rate was estimated (after Gatlin et al., 1992) according to...

$$g_{2-1} = \frac{W_2^{1-x} - W_1^{1-x}}{t_2 - t_1} \quad \text{Equation 5}$$

where  $W_1$  and  $W_2$  are an individual's weight at two different ages,  $t_1$  and  $t_2$ , respectively, and  $x$  is a fractional exponent of weight less than unity (Parker and Larkin 1959). For red drum, the value for  $x$  was 0.66 (Garces, 1991). Growth rates were estimated for two different growth intervals: 148 - 189 days post-spawning  $\{t_1\}$ , and 190 - 208 days post-spawning  $\{t_2\}$ .

Significance of the effects on phenotype (growth rate) involved in the experimental design, i.e., replicate (tank) effect, spawning-event effect, family (genetic) effect (nested within spawn), and replicate (tank) x spawning-event interaction was tested by means of analysis of variance (ANOVA), as implemented in the PROC GLM procedure of SAS 8.2 (SAS, 2001) and using type IV sums-of-square as before. The replicate (tank) x

spawning-event interaction effect was non-significant and was consequently not included in the selected model. Variance components, and their standard errors, associated with each effect accounted for in the selected model (below) were estimated by the REML algorithm as implemented in VCE-4.0 (Groeneveld and Kovac, 1990). The selected model was...

$$y_{ijk} = \mu + m_i + sp_j + f_k(SP) + e_{ijkl} \quad \text{Equation 6}$$

where  $\mu$  is the overall mean,  $m_i$  represents the replicate (tank) effect,  $sp_j$  represents the spawning-event effect,  $f_k(SP)$  represents the family (genetic) effect (nested within spawn), and  $e_{ijkl}$  represents random error. Narrow-sense heritability of juvenile growth rate was estimated for the two growth intervals (148 - 189 days post-spawning and 190 - 208 days post-spawning) as twice the ratio of the genetic (family) component divided by the total phenotypic variance (replicate plus spawning event plus family {nested within spawn} plus residual), after Becker (1984).

### 3.7. *Heritability of cold tolerance*

After the growth-rate experiment was terminated (250 days post-spawning), 30 fingerlings from each of seven spawns were PIT-tagged and allocated randomly into three replicate tanks (70 fingerlings per tank). Refrigeration units (chillers) were placed into each of the three experimental tanks; initial water temperature was 25 °C. Starting 3 days following transfer, water temperature in each experimental tank was reduced gradually by 1 °C/day until the temperature reached 12 °C. Thereafter, the temperature in each experimental tank was reduced at the rate of 0.5 °C / day until all

fish had expired. Dissolved oxygen, salinity, temperature, and amount of feed provided to each experimental tank also were monitored daily. Death statistics (date, time, water temperature, and fish length and weight at death) was recorded for each individual.

Significance of the effects on phenotype (cold tolerance) involved in the experimental design, i.e., replicate (tank) effect, family (genetic) effect, and replicate (tank) x family (genetic) interaction effect ( $m_i \times f_j$ ) was tested as before by means of ANOVA carried out using the PROC GLM procedure of SAS 8.2 (SAS, 2001), with type IV sums-of-square used to test significance of each effect. The replicate (tank) x family (genetic) interaction effect was non-significant and consequently was not included in the selected model. Variance components, and their standard errors, associated with each effect accounted for in the selected model were estimated by the REML method as implemented in VCE-4.0 (Groeneveld and Kovac, 1990). The model selected was...

$$y_{ijk} = \mu + m_i + f_j + e_{ijk} \quad \text{Equation 7}$$

where  $\mu$  indicates the overall mean,  $m_i$  represents the replicate (tank) effect,  $f_j$  represents the family (genetic) effect, and  $e_{ijk}$  represents the random error. Narrow-sense heritability of cold tolerance was calculated as twice the ratio of the genetic (family) component divided by the total phenotypic variance (replicate plus family plus residual), after (Becker, 1984).

### 3.8 *Test of Mendelian inheritance*

Two full-sib families of 125 individuals each (chosen from among the 13 separate spawning events) were genotyped at 31 nuclear-encoded microsatellites. Mendelian

segregation of alleles at each microsatellite was tested by using Chi square ( $X^2$ ) goodness-of-fit tests. Genotypes expected among full-sib offspring from a given mating were based on the genotypes of the sire and dam. Tests of independent assortment between pairs of microsatellites were based on the genotypes of mated pairs (sire x dam) at the 31 microsatellites. Dihybrid (individuals heterozygous at two microsatellite loci) sires and dams were identified and their offspring tested (via  $X^2$  goodness-of-fit tests) for independent assortment of alleles at each microsatellite. The genotype data were accessed in an Excel file and  $X^2$  tests carried out in SPSS 11.5.0 (SPSS, 2002).

## 4. RESULTS

### 4.1. *Effective population size*

Data from the 13 spawns sampled from nine brood tanks in 2002 are presented in Table 1; data per brood tank include number of spawns, number of contributing dams and sires, number of families generated, and number of progeny genotyped (range = 111 – 125 per spawn). The number of spawns per brood tank over the time interval sampled was as follows: one (six tanks), two (two tanks), and three (one tank). The number of spawning combinations (families) generated per brood tank varied from one (one dam x one sire) to six (three dams x two sires). On average, more families were generated per brood tank if multiple spawns occurred in a brood tank. In one brood tank (BB-2), genotype data indicated a mismatch in the sex identification (some offspring were assigned to two breeders putatively of the same sex); while in another brood tank (BB-11), genotype data indicated that although all six brood fish had contributed to the spawn, only two of the three fish tentatively identified as females were the same sex. Prior to sampling, personnel at TPWD had tentatively identified each tank as containing three females and two males. Assuming identification by TPWD personnel was mostly accurate, the most parsimonious hypothesis was that brood tank BB-2 contained four females and one male, while brood tank BB-11 contained two females and three males.

The maximum (expected) genetic effective size ( $N_e$ ) for each brood tank, based on Equation 1 and assuming that all three individuals of one sex mated with the two individuals of the opposite sex, would be 4.8. Considered over all nine brood tanks,

Table 1  
Spawning data from 2002

Brood tank	BB-1	BB-2	BB-7	BB-8	BB-11	BB-12	VB3-1	VB3-3	VB4-1	Total
Spawns	1	2	1	3	2	1	1	1	1	13
Dams	1	3	3	2	2	1	1	1	2	16
Sires	1	1	2	2	3	2	2	1	2	16
Families	1	3	6	4	6	2	2	1	4	29
Progeny	123	249	125	368	249	123	111	124	125	1597



and assuming all tanks contribute equally to the offspring population, the maximum(expected)  $N_e$  would be 43.2. The observed  $N_e$  for each of the nine brood tanks surveyed in this study, however, ranged from 2.0 to 4.8. Considered over all nine brood tanks, and assuming all tanks contribute equally to offspring population, the observed  $N_e$  was 27.0. These observed estimates of  $N_e$  reflect only the number of females and males that actually spawned in each brood tank and assume that family size per spawning pair was equal across all spawning pairs.

Parental assignments, based on the genotype data, revealed considerable differences in family size among spawning pairs (Appendix 3 and 4). As an example, while all six broodfish in tank BB-7 contributed to the spawn, 98% of the sampled progeny came from two of the three dams, while 97% came from one of the two sires. Similarly, in tank VB4-1, 84% of the sampled progeny came from one of two dams (the third dam did not contribute to the sampled progeny), while 97% of the sampled progeny came from one of two sires.  $N_e$  estimates derived by considering the variation in family size per mating pair per spawn (Equation 2) ranged from 1.65 - 3.82 per spawn (13 spawns) and from 1.65 - 3.52 per brood tank (nine tanks). Considered over all nine brood tanks, and assuming all tanks contribute equally to offspring population, the  $N_e$  estimate based on observed variation in family size was 19.4.

A third estimator of  $N_e$ , based on Equation 3, considers the contribution of individual brood tanks to a given release. Using the actual data on the number of mating pairs that spawned in each brood tank, and their respective family size, three different possible patterns of brood-tank contribution were considered (Table 2): (i) the number of fish released per brood tank is the same (symmetric); (ii) the number of fish released per brood tank differs (asymmetric); and (iii) the number of fish released per brood tank is proportional to the estimated effective size in each brood tank. For the second possibility (asymmetric release), different proportional contributions from each brood tank were generated randomly but with the largest contribution being 15 times larger than the smallest one; for the third possibility, the estimate of effective size was based on estimates for each brood tank, derived using Equation 2. Estimates of  $N_e$  under these three possibilities were 19.7 (symmetric release), 9.3 (asymmetric release), and 20.8 (proportional to  $N_e$  of each brood tank).

Table 2

Variation in contribution of brood tanks

Brood tank	$N_{eBT}^a$	Proportional contribution to released fish		
		Symmetric	Asymmetric	Proportional to $N_{eBT}$
BB-1	2.00	1/9	30/100	96/1000
BB-2	2.84	1/9	5/100	136/1000
BB-7	2.05	1/9	4/100	98/1000
BB-8	3.52	1/9	2/100	169/1000
BB-11	2.93	1/9	10/100	140/1000
BB-12	2.03	1/9	5/100	97/1000
VB3-1	1.82	1/9	30/100	88/1000
VB3-3	2.00	1/9	4/100	96/1000
VB4-1	1.65	1/9	10/100	79/1000

<sup>a</sup> $N_{eBT}$  is the effective size estimated for each brood tank based on Equation 2.

#### 4.2. *Heritability of early-larval growth*

Approximately 125 fingerlings from each of the 13 spawns sampled in 2002 were genotyped and assigned unequivocally to their parents (Appendix 4). Genotypes of parents and offspring from each of the 13 spawns in 2002 may be found in Appendix 5. A total of 16 dams and 16 sires contributed to the total of 29 families (Table 1). The average ( $\pm$  SD) number of progeny (and range) generated per dam and per sire were  $99.3 \pm 63.7$  (2 - 244) and  $99.3 \pm 71.4$  (2 - 249), respectively. Mean (standard deviation) and range of weight and length of larvae from each of 13 spawns are given in Table 3. The estimated phenotypic correlation between length and weight was  $0.97 \pm 0.01$ .

Variance components of early larval growth (based on weight data) were partitioned into spawning-event and family (genetic) effects (Equation 4); both effects were found to contribute significantly to the phenotypic variance in weight (Table 4). The estimate of heritability of early larval growth (weight) was  $0.07 \pm 0.03$ .

#### 4.3. *Heritability of juvenile growth rate*

A total of 450 juveniles from 10 spawns (45 fish per spawn) in 2003 were placed randomly into three replicate experimental tanks and used in the experiment to estimate heritability of juvenile growth rate. A total of 14 dams and 10 sires contributed to the total of 19 families (Appendix 6). Genotypes of parents and offspring, and weight and length of each offspring at each of three measurement periods, from each of the 10 spawns (identified by replicate tank) may be found in Appendix 7. The average ( $\pm$  SD) number of progeny (and range) generated per dam and per sire were  $21.4 \pm 14.7$  (2 - 40)

Table 3

Mean (standard deviation) and range of weight and length of 124-125 larvae from each of 13 spawns sampled in 2002 (Length was measured to the nearest 0.5 mm)

Spawn	Number of Larvae	Weight (g)		Length (mm)	
		Mean (SD)	Range	Mean (SD)	Range
1	125	0.300 (0.049)	0.176 - 0.489	32.7 (1.9)	28 – 38
2	125	0.216 (0.062)	0.106 - 0.704	29.1 (2.4)	24 – 44
3	125	0.183 (0.101)	0.065 - 0.536	27.4 (5.1)	19.5 – 42
4	124	0.313 (0.115)	0.173 - 0.878	33.4 (3.9)	27 – 48
5	125	0.293 (0.102)	0.181 - 0.848	32.1 (3.3)	28 – 48
6	125	0.241 (0.040)	0.166 - 0.413	29.8 (1.6)	25 – 36
7	125	0.201 (0.089)	0.117 - 0.787	29.6 (3.7)	24 – 47
8	125	0.208 (0.070)	0.141 - 0.701	28.7 (2.7)	24 – 44
9	125	0.266 (0.156)	0.112 - 1.015	30.1 (5.4)	22.5 – 50
10	125	0.225 (0.083)	0.123 - 0.689	28.5 (3.4)	23 – 43
11	125	0.220 (0.071)	0.119 - 0.636	29.1 (3.1)	23.5 – 43
12	125	0.229 (0.091)	0.087 - 0.543	30.0 (4.1)	22 – 41
13	125	0.417 (0.073)	0.243 - 0.700	36.2 (2.4)	29 – 44

Table 4

Results of analysis of variance for early larval growth (weight)

Source	Degree of freedom	Type IV SS	Mean square	F	P (F = 0)
Spawn	11	2.5691	0.2336	30.22	0.000
Family (Spawn)	18	0.4348	0.0242	3.13	0.000

and  $27.3 \pm 22.0$  (2 - 66), respectively. Weight and length of juveniles in each replicate tank were recorded at three time periods (148, 189, and 208 days post-spawning). Mean (standard deviation) and range of weight and length of fish, by family, in each replicate tank at the three time periods may be found in Appendix 8. The phenotypic correlations between weight and length at the two time intervals (all three replicates combined) were  $0.95 \pm 0.02$  and  $0.96 \pm 0.02$ , respectively. Instantaneous exponential growth rates for weight and length were calculated for two growth intervals (148 to 189 days post-spawning and 189 to 208 days post-spawning). Mean (standard deviation) and range of growth rates (based on weight) at the two growth intervals are presented by family in Table 5.

The phenotypic variance of juvenile growth rates (based on weight) was partitioned into components due to the replicate (tank) effect, spawning-event effect, family (genetic) effect (nested within spawn), and replicate (tank) x spawning-event interaction effects. The family (genetic) effect was found to contribute significantly to the phenotypic variance in juvenile growth rate at both time intervals. A significant replicate (tank) effect occurred only at the second time interval, while a significant spawning-event effect occurred only at the first time interval (Table 6). A replicate (tank) x spawning event interaction effect was not significant at either time interval (Table 6), and was therefore not included in the estimation of heritability. Estimates of heritability for juvenile growth rate (weight) at the first and second time intervals were generated using the model specified in Equation 6 and were  $0.52 \pm 0.21$  and  $0.20 \pm 0.10$ , respectively.

Table 5

Mean (standard deviation) and range of instantaneous exponential growth rates (based on weight) at two growth intervals

Family	148 – 189 days post-spawning		189 – 208 days post-spawning	
	Growth rate		Growth rate	
	Mean (SD)	Range	Mean (SD)	Range
1	0.677 (0.205)	0.357 – 1.198	0.564 (0.145)	0.348 – 1.095
2	0.696 (0.192)	0.119 – 1.045	0.457 (0.174)	0.026 – 0.857
3	0.484 (0.169)	0.147 – 0.819	0.382 (0.104)	0.209 – 0.561
4	---	---	---	---
5	0.778 (0.225)	0.316 – 1.197	0.553 (0.164)	0.075 – 0.965
6	0.804 (0.102)	0.643 – 0.989	0.482 (0.144)	0.172 – 0.689
7	0.629 (0.137)	0.412 – 0.825	0.492 (0.131)	0.268 – 0.648
8	0.538 (0.069)	0.450 – 0.619	0.442 (0.107)	0.292 – 0.549
9	0.613 (0.189)	0.313 – 1.154	0.467 (0.154)	0.021 – 0.690
10	0.874 (0.192)	0.738 – 1.010	0.371 (0.128)	0.222 – 0.491
11	0.378 (0.183)	0.248 – 0.508	0.416 (0.208)	0.100 – 0.613
12	0.920 (0.164)	0.634 – 1.355	0.547 (0.145)	0.221 – 0.842
13	0.694 (0.171)	0.313 – 0.957	0.661 (0.859)	0.263 – 4.659
14	0.641 (0.264)	0.403 – 1.074	0.521 (0.137)	0.423 – 0.822



Table 6

Results of analysis of variance for instantaneous growth rates (based on weight) at two growth intervals

Growth Interval <sup>a</sup>	Source	Degree of freedom	F	P (F = 0)
Interval 1	Tank	2	1.88	0.156
	Spawn	8	8.90	0.000
	Family (Spawn)	11	2.99	0.001
	Tank x Spawn	16	1.68	0.054
Interval 2	Tank	2	7.47	0.001
	Spawn	8	1.48	0.167
	Family (Spawn)	11	2.51	0.006
	Tank x Spawn	16	1.18	0.289

<sup>a</sup> Interval 1 = 148 to 189 days post-spawning; Interval 2 = 189 to 208 days post-spawning.

#### 4.4. *Heritability of cold tolerance*

A total of 30 fingerlings from each of seven spawns (210 fish total) sampled in 2003 were allocated randomly to three replicate tanks for the cold-tolerance experiment. A total of 13 dams and 9 sires contributed to a total of 17 families (Appendix 9). Genotypes (and sire and dam from a TPWD brood tank) of each experimental fish are given in Appendix 10a. The average ( $\pm$  SD) number of progeny (and range) generated per dam and per sire were  $15.3 \pm 11.5$  (1 - 37) and  $22.1 \pm 15.3$  (1 - 42), respectively. Vital statistics (duration of cold exposure; day, time and temperature at death; and final weight and length) for each experimental fish are given in Appendix 10b. Death statistics (survival time and temperature at death) of 199 of the fish may be found in Appendix 11; eleven of the fish died during the course of the experiment, presumably from cannibalism. A mortality-temperature curve (based on replicate tank #1) generated from the data in Appendix 11 is shown in Figure 1. Analysis of variance indicated that the family (genetic) effect was significant, whereas the replicate (tank) and replicate x family interaction effects were not (Table 7). Variance components were estimated using the model specified in Equation 7. The estimate of heritability for cold tolerance was  $0.30 \pm 0.11$ .

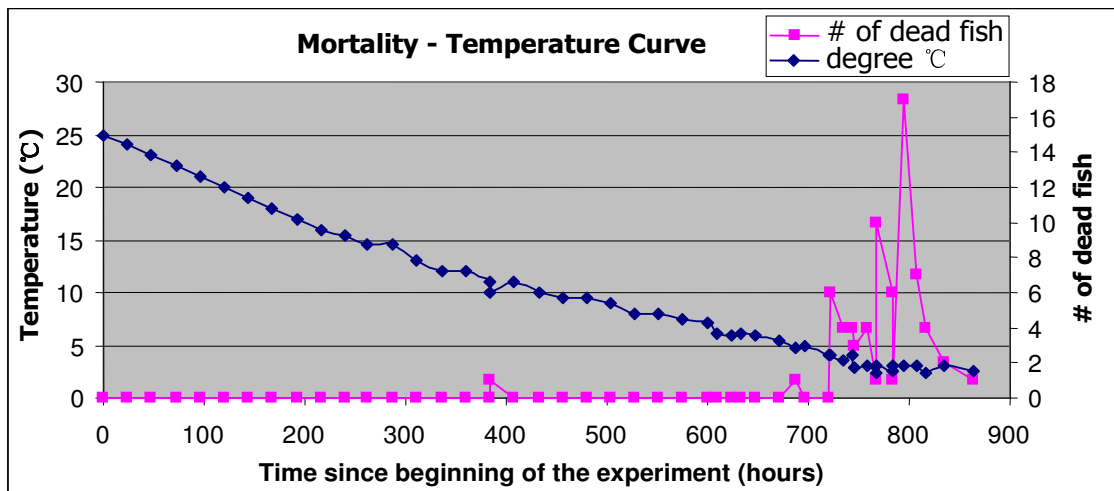


Fig. 1. Mortality-temperature curve (from replicate tank # 1).

Table 7

Results of analysis of variance for cold tolerance

Source	Degree of Freedom	Type IV SS	Mean square	F	P (F = 0)
Tank	2	6261.40	3130.70	2.56	0.0805
Family	17	59773.34	3516.08	2.87	0.0003
Tank x Family	21	19200.96	914.33	0.75	0.7781

#### 4.5. *Test of Mendelian inheritance*

Parents and progeny from two full-sib families (125 fingerlings per family) from the 2002 spawn were genotyped at 31 microsatellites (Appendix 12). Mendelian segregation at each microsatellite, when at least one parent was heterozygous, was tested using  $X^2$  goodness-of-fit tests. Genotypes at a given microsatellite expected among offspring from a given mating pair were predicted based on the genotypes at that microsatellite of the sire and dam. The number of alleles examined for segregation at each of the 31 microsatellites in both families is given in Table 8.

The distribution of probability values from 57 separate  $X^2$  goodness-of-fit tests carried out are shown in Figure 2. Segregation at two microsatellites (*Soc* 243 and *Soc* 444) in Family 1 and one microsatellite (*Soc* 60) in Family 2 could not be tested for Mendelian segregation as both parents were homozygous for alleles at these three microsatellites. Fortunately, both parents in the Family 1 were heterozygous at *Soc* 60, while at least one parent in Family 2 was heterozygous at *Soc* 243 and *Soc* 444. Segregation at two microsatellites (*Soc* 201 and *Soc* 401) was not tested because of conflicts between the observed genotypic classes among offspring and expected genotypic classes generated from the parental genotypes (see below). Probability values of 22 (of 27) tests involving Family 1 were non-significant ( $P < 0.05$ ); significant deviation from Mendelian expectation was observed at microsatellites *Soc* 410, *Soc* 419, *Soc* 412, *Soc* 156, and *Soc* 138 ( $0.048 \geq P \geq 0.014$ ). Similarly, probability values of 25 (of 30) tests involving Family 2 were non-significant. Significant deviations from Mendelian expectations were observed at microsatellites *Soc* 400, *Soc* 11, *Soc* 415, *Soc*

Table 8

Number of alleles examined for segregation over all 31 microsatellites in two families

Microsatellite	Family 1	Family 2
<i>Soc</i> 11	3	2
<i>Soc</i> 19	3	3
<i>Soc</i> 44	4	4
<i>Soc</i> 60	2	--
<i>Soc</i> 83	3	4
<i>Soc</i> 85	4	2
<i>Soc</i> 99	3	4
<i>Soc</i> 138	2	3
<i>Soc</i> 140	2	2
<i>Soc</i> 156	2	2
<i>Soc</i> 201	4	3
<i>Soc</i> 206	2	2
<i>Soc</i> 243	--	3
<i>Soc</i> 400	3	3
<i>Soc</i> 401	3	4
<i>Soc</i> 402	3	3
<i>Soc</i> 404	4	2
<i>Soc</i> 407	4	4
<i>Soc</i> 410	3	4
<i>Soc</i> 412	4	4
<i>Soc</i> 415	4	3
<i>Soc</i> 416	4	3
<i>Soc</i> 417	3	2
<i>Soc</i> 419	4	3
<i>Soc</i> 423	3	4
<i>Soc</i> 424	3	3
<i>Soc</i> 428	3	4
<i>Soc</i> 432	3	3
<i>Soc</i> 433	2	4
<i>Soc</i> 444	--	2
<i>Soc</i> 445	3	3

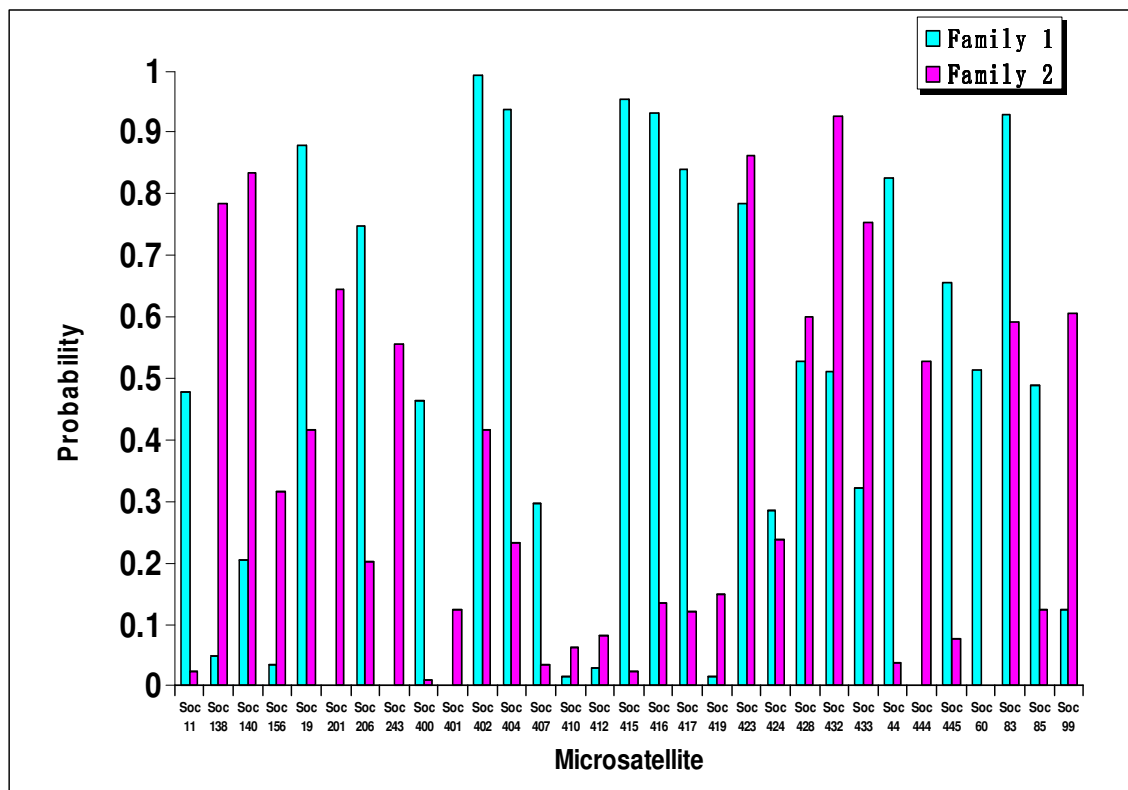


Fig. 2. Probability values from 59 Chi-square goodness-of-fit tests of Mendelian segregation at 31 microsatellites.

407, and *Soc* 44 ( $0.037 \geq P \geq 0.001$ ). Following sequential Bonferroni correction (Rice, 1989) for multiple tests performed simultaneously, all 57 tests were non-significant, indicating that all 31 microsatellites segregated according to Mendelian expectations.

The genotypes observed at microsatellites *Soc* 201 and *Soc* 401 among progeny in Family 1 when compared to the genotypes of the parents indicated possible occurrence of null alleles. At *Soc* 201, one parent was heterozygous for alleles 232 and 236, while the other parent appeared to be homozygous for allele 234. Expected genotypes (frequencies) expected among the progeny were thus 232/234 heterozygotes (50%) and 234/236 heterozygotes (50%). Four (inferred) genotypes in approximately equal frequencies, however, were observed among progeny: 232/234 heterozygotes, 232/232 homozygotes, 234/236 heterozygotes, and 236 homozygotes. A Chi-square test of the hypothesis that the parent assumed to be homozygous for allele 234 was actually heterozygous for allele 234 and a null allele was non-significant  $P = 0.394$ , Table 9).

Similarly, genotypes observed at *Soc* 401 among progeny in Family 1 suggested occurrence of a null allele. Here, one parent apparently was homozygous for allele 176, while the other parent was heterozygous for alleles 178 and 200. Expected genotypes (frequencies) among their progeny were 176/178 (50%) and 176/200 (50%). Four (inferred) genotypes in approximately equal frequencies were observed among the progeny: 176/178 and 176/200 heterozygotes and 178 and 200 homozygotes. A Chi-square test of the hypothesis that the parent assumed to be homozygous for allele 176 was actually heterozygous for allele 176 and a null allele was non-significant ( $P = 0.974$ , Table 9).



Table 9

Results of Chi-square goodness-of-fit tests for *Soc* 201 and *Soc* 401 under the assumption that null alleles were segregating at both microsatellites

Micro-satellite	Parental genotypes	Progeny genotypes	Observed	Expected	Chi-square	Degrees of freedom	Probability
<i>Soc</i> 201	232/236	232/234	34	28.5	2.98	3	0.394
	234/null	232/null	25	28.5			
		234/236	32	28.5			
		null/236	23	28.5			
<i>Soc</i> 401	176/null	176/178	31	30.25	0.223	3	0.974
	178/200	176/200	28	30.25			
		178/null	31	30.25			
		null/200	31	30.25			

Tests of independent assortment between pairs of microsatellites were based on the genotypes of sires and dams in the two full-sib families. All dihybrid sires and dams (i.e., individuals heterozygous at any two of the 31 microsatellites) were identified and their offspring tested for independent assortment (of alleles) via Chi-square goodness-of-fit tests. Theoretically, there were 465 combinations of any two microsatellites, given 31 microsatellites total. In order to carry out the tests efficiently, the 465 combinations were sorted into five categories based on the two-locus genotypes of the sires and dams. The number of expected genotypes among full-sib offspring from a given mating pair, depending on the genotypes of both parents, was 16, 12, 9, 8, and 6 for the five categories. As examples, if both parents were heterozygous for different alleles at two microsatellites, there would be 16 different two-locus genotypes expected in equal frequencies among the progeny (Table 10); whereas, if one parent was heterozygous at one microsatellite and homozygous at the other microsatellite, while the other parent was heterozygous for different alleles at both microsatellites, there would be eight different two-locus genotypes expected in equal frequencies among the progeny (Table 11).

Table 10

Genotypes (16) expected among progeny from crosses between parents heterozygous for different alleles (Genotypes expected are in bold)

<u>Genotypes</u>	<u>Microsatellite 1</u>		<u>Microsatellite 2</u>	
Female	ab		ef	
Male	cd		gh	
Gametes	ae	be	af	bf
cg	<b>aceg</b>	<b>bceg</b>	<b>acfg</b>	<b>bcfg</b>
dg	<b>adeg</b>	<b>bdeg</b>	<b>adfg</b>	<b>bdfg</b>
ch	<b>aceh</b>	<b>bceh</b>	<b>acfh</b>	<b>bcfh</b>
dh	<b>adeh</b>	<b>bdeh</b>	<b>adfh</b>	<b>bdfh</b>

a - d are different alleles at microsatellite 1, while e – h are different alleles at microsatellite 2. Independent assortment of the two microsatellites leads to the expectation that all 16 possible genotypes will occur in equal frequencies.

Table 11

Genotypes (8) expected among progeny from crosses where one parent is heterozygous at one microsatellite and homozygous at the other microsatellite; while the other parent is heterozygous for different alleles at both microsatellites (Genotypes expected are in bold)

<u>Genotypes</u>	<u>Microsatellite 1</u>	<u>Microsatellite 2</u>		
Female	ab	ee		
Male	cd	fg		
Gametes	ae	be	ae	be
cf	<b>acef</b>	<b>bcef</b>	acef	bcef
df	<b>adef</b>	<b>bdef</b>	adef	Bdef
cg	<b>aceg</b>	<b>bceg</b>	aceg	bceg
dg	<b>adeg</b>	<b>bdeg</b>	adeg	bdeg

a - d are different alleles at microsatellite 1, while e - g are different alleles at microsatellite 2. Independent assortment of the two microsatellites leads to the expectation that all eight different genotypes will occur in equal frequencies

Following sequential Bonferroni correction for multiple tests performed simultaneously (Rice, 1989), 14 (of 465 total) tests of pairwise of independent assortment in Family 1 and 17 tests in Family 2 were significant. Pairs of microsatellites found to be assorting non-independently in both families are shown in Table 12. By comparing significant tests in both families, from two to five microsatellites could be assigned into seven different linkage groups (Table 13). The remaining 11 microsatellites assorted independently from each other and from those found to be linked, which means they could be assigned into a maximum of 11 different linkage groups.

Several of the PCR primers developed by O'Malley et al. (2003) for red drum microsatellites were generated from single clones and hence can be assigned to the same linkage group. These included primers for *Soc 432/Soc 433*, *Soc 444/Soc 445*, and *Soc 415/Soc 416/Soc 407* (linkage groups 5, 6, and 7, respectively; Table 13). Other PCR primers generated from single clones by O'Malley et al. (2003) were *Soc 409/Soc 410*, *Soc 403/Soc 404*, and *Soc 444/Soc 445*. Based on the above, *Soc 409* can be assigned to linkage group 3, and *Soc 403/Soc 404* and *Soc 444/Soc 445* can be tentatively assigned to two additional linkage groups (Table 13).

Table 12

Microsatellite pairs that showed significant departure from independent assortment in two families

No. of pairs	Microsatellite 1	Microsatellite 2	Degree of freedom	P-value
Family 1				
1	<i>Soc</i> 201	<i>Soc</i> 412	15	<0.0001
2	<i>Soc</i> 401	<i>Soc</i> 402	15	0
3	<i>Soc</i> 11	<i>Soc</i> 400	7	<0.0001
4	<i>Soc</i> 11	<i>Soc</i> 407	15	0
5	<i>Soc</i> 400	<i>Soc</i> 407	7	<0.0001
6	<i>Soc</i> 83	<i>Soc</i> 432	15	<0.0001
7	<i>Soc</i> 432	<i>Soc</i> 433	15	0
8	<i>Soc</i> 99	<i>Soc</i> 445	15	0
9	<i>Soc</i> 44	<i>Soc</i> 415	15	0
10	<i>Soc</i> 44	<i>Soc</i> 416	15	0
11	<i>Soc</i> 44	<i>Soc</i> 417	15	0
12	<i>Soc</i> 415	<i>Soc</i> 416	15	0
13	<i>Soc</i> 415	<i>Soc</i> 417	15	0
14	<i>Soc</i> 416	<i>Soc</i> 417	15	0
Family 2				
1	<i>Soc</i> 201	<i>Soc</i> 412	15	<0.0001
2	<i>Soc</i> 401	<i>Soc</i> 402	7	0
3	<i>Soc</i> 410	<i>Soc</i> 428	15	0
4	<i>Soc</i> 11	<i>Soc</i> 400	7	0
5	<i>Soc</i> 11	<i>Soc</i> 407	7	0
6	<i>Soc</i> 83	<i>Soc</i> 432	7	<0.0001
7	<i>Soc</i> 83	<i>Soc</i> 433	15	<0.0001
8	<i>Soc</i> 99	<i>Soc</i> 444	7	0
9	<i>Soc</i> 99	<i>Soc</i> 445	15	0
10	<i>Soc</i> 444	<i>Soc</i> 445	7	0
11	<i>Soc</i> 44	<i>Soc</i> 416	7	<0.0001
12	<i>Soc</i> 44	<i>Soc</i> 417	5	0
13	<i>Soc</i> 243	<i>Soc</i> 416	15	<0.0001
14	<i>Soc</i> 243	<i>Soc</i> 417	11	0
15	<i>Soc</i> 415	<i>Soc</i> 416	7	<0.0001
16	<i>Soc</i> 415	<i>Soc</i> 417	5	0
17	<i>Soc</i> 416	<i>Soc</i> 417	15	0

Table 13

Linkage groups inferred from pairwise tests of independent assortment (this study) and from initial development of PCR primers (O'Malley et al., 2003)

Linkage group	Microsatellites
1	<i>Soc</i> 201, <i>Soc</i> 412
2	<i>Soc</i> 401, <i>Soc</i> 402
3	<i>Soc</i> 409*, <i>Soc</i> 410, <i>Soc</i> 428,
4	<i>Soc</i> 11, <i>Soc</i> 400, <i>Soc</i> 407,
5	<i>Soc</i> 83, <i>Soc</i> 432, <i>Soc</i> 433
6	<i>Soc</i> 99, <i>Soc</i> 444, <i>Soc</i> 445
7	<i>Soc</i> 44, <i>Soc</i> 243, <i>Soc</i> 415, <i>Soc</i> 416, <i>Soc</i> 417
8	<i>Soc</i> 403*, <i>Soc</i> 404*
9	<i>Soc</i> 437*, <i>Soc</i> 438*

\* Linkage groups or relationships inferred from O'Malley et al. (2003).

## 5. CONCLUSION

This study includes three different components: (i) estimates of genetic effective size ( $N_e$ ) of released populations in the TPWD red drum stock-enhancement program; (ii) estimates of the heritability ( $h^2$ ) of early-larval growth, growth rate of juveniles, and cold tolerance of red drum; and (iii) tests of Mendelian segregation and pairwise independent assortment of 31 nuclear-encoded microsatellites, leading to the development of a rudimentary genetic linkage map.

### 5.1. *Effective size*

The genetic effective size of a hatchery-released population has been discussed and/or evaluated for several exploited or rare and threatened fish species, including chinook salmon, *Oncorhynchus tshawytscha* (Hedrick et al., 1995), brown trout, *Salmo trutta* (Hansen et al., 2000), Gulf sturgeon, *Acipenser oxyrinchus desotoi* (Tringali and Bert, 1998), Japanese flounder, *Paralichthys olivaceus* (Sekino et al., 2003), and red drum, *Sciaenops ocellatus* (Tringali and Bert, 1998; Chapman et al., 2002). The primary concerns regarding genetic effective population size of a released population in stock-enhancement are (i) reduced genetic diversity and lower fitness among released fish because of non-random representation of a small number of breeders (Su et al., 1996; Laikre et al., 1998; Rye and Mao, 1998), (ii) the possibility that less fit released fish may integrate genetically into the ‘wild’ population and potentially reduce the effective population size of the ‘wild’ population (Ryman and Laikre, 1991).

There are three levels or stages within the TPWD stock-enhancement program



where the genetic effective size of a released population could be affected: (i) number of families generated per brood tank, (ii) family size per spawning pair (per brood tank), and (iii) number of offspring per brood tank used in releases. With respect to the first, the TPWD stock-enhancement program normally utilizes three dams and two sires in each of several brood tanks. There are thus six possible dam x sire combinations (families) that could be generated in each brood tank. As shown in Table 14, variation in the actual number of families generated per brood tank directly affects effective size ( $N_e$ ). Assuming that more than one family is generated within a brood tank during a spawning event, the second level regards the family size (number of progeny) produced by each spawning pair. Differences in family size within a brood tank lead to non-random representation of individual brood fish among progeny within a brood tank, thus reducing effective size relative to that expected when family sizes are equivalent (Chevassus, 1989). Finally, differences in the number of progeny released per brood tank when progeny from multiple brood tanks are combined for release also can lead to non-random representation of individual brood fish, again reducing effective size of the released population relative to that expected when the same numbers of progeny are released from each brood tank (Ryman and Laikre 1991).

In this study, the number of spawning pairs, and the family size generated from each spawning pair, in each of nine brood tanks at a TPWD facility were followed over a two-week period. Seven of the brood tanks contained the expected number of dams (3) and sires (2); one brood tank contained four dams and one sire, while another brood tank contained two dams and three sires. Spawning activity was followed over the

Table 14

Variation in family number and reduction in expected effective size ( $N_e$ ) estimated after Wright (1969)

Family number	Spawning dams	Spawning sires	Expected $N_e$
6	3	2	4.8
4	2	2	4.0
3	3	1	3.0
2	2	1	2.7
2	1	2	2.7
1	1	1	2.0

two-week period for these 45 broodfish (27 dams and 18 sires). The number of spawns per brood tank over the two-week period ranged from one to three, with 13 spawns occurring overall. If all dams and all sires generated progeny (i.e., all possible matings occurred), and if each spawning pair generated equal numbers of progeny (i.e., the variance in family size was zero), the maximum expected effective size (estimated following Wright, 1969) per brood tank would be 4.8, with a maximum expected effective size over all nine brood tanks of 40.9 (Table 15, Row A).

Based on parentage analysis, a total of 32 (16 dams and 16 sires) of the 45 brood fish spawned over the two-week period. The total number of spawning pairs (families) generated over all nine brood tanks was 29, with the number of families generated per brood tank ranging from one to six (average family per brood tank of 3.2). The actual  $N_e$  for each of the nine brood tanks surveyed in this study thus ranged from 2.0 to 4.8 (Table 15). Considered over all nine brood tanks, and assuming that the number of progeny generated per family (i.e., family size) was equivalent, the maximum  $N_e$  expected would be 27.0 (Table 15, Row B).

Parental assignment of progeny generated during the two-week spawning period revealed that more than one mating pair produced spawn in seven of the brood tanks, with multiple spawning occurring in three brood tanks, and that there were considerable differences in family size among spawning pairs. Estimates of  $N_e$  per brood tank, derived by considering the variation in family size per mating pair per spawn, ranged from 1.65 - 3.52 per brood tank (Table 15, Row C), with an average  $N_e$  per brood tank of 2.29. Considered over all nine brood tanks, and assuming that the number of progeny

Table 15

$N_e$  values for all nine brood tanks individually and for a released population (total  $N_e$ ) assuming family size per brood tank is equivalent and equal numbers of progeny per brood tank comprise the released population

<u>Scenario*</u>	BB-1	BB-2	BB-7	BB-8	BB-11	BB-12	VB3-1	VB3-3	VB4-1	Total $N_e$
A	4.80	3.20	4.80	4.80	4.80	4.80	4.80	4.80	4.80	40.9
B	2.00	3.00	4.80	4.00	4.80	2.67	2.67	2.00	4.00	27.0
C	2.00	2.84	2.05	3.52	2.93	2.03	1.82	2.00	1.65	19.4

- \*(A) Assumes that (i) all possible pairwise matings (families) within a brood tank occur, (ii) all families contain equal numbers of progeny (i.e., family sizes are equivalent), and (iii) an equal number of progeny from each brood tank comprise the released population.
- (B) Based on the actual number of pairwise mating (families) within each brood tank and assuming (i) all families contain equal numbers of progeny (i.e., family sizes are equivalent), and (ii) an equal number of progeny from each brood tank comprise the released population.
- (C) Based on the actual number of pairwise matings (families) and the actual size of each family within a brood tank, and assuming that an equal number of progeny from each brood tank comprise the released population.

generated per brood tank was equivalent, the maximum  $N_e$  expected would be 19.4 (Table 15, Row C).

The third level or stage in a stock-enhancement program where  $N_e$  of a released population could be affected is in the number of offspring per brood tank used in releases. Using the estimates of  $N_e$  in each of the nine brood tanks (Table 15, Row C), three different released populations were simulated to evaluate potential effects on  $N_e$ : (i) equal number of progeny released from each brood tank (symmetric); (ii) unequal number of progeny released from each brood tank (asymmetric); and (iii) progeny released from each brood tank proportional to the estimate of effective size (Table 15, Row C) in each brood tank. Values of  $N_e$  generated were 19.7 (symmetric), 9.3 (asymmetric), and 20.8 (proportional).

The foregoing results demonstrated that the maximum effective size of a population released from the nine brood tanks would be about half of that theoretically possible if all 45 brood fish had contributed equally to the released population. The effects on effective size occurred both in the number of spawning fish in each brood tank (observed  $N_e$  over all tanks of 27.0 versus expected  $N_e$  over all tanks of 40.9) and in the number of progeny (family size) produced per actual spawning pair (observed  $N_e$  over all tanks of 19.4 versus expected  $N_e$  over all tanks of 27.0). The variation in number of spawning fish per spawning event, as well as differences in family size per spawning pair, could be due to any number of essentially uncontrollable factors ranging from differences in general behavior to differences in general health or nutritional state to different responses to stress from handling (R. Vega, personal communication). However, over a

longer period of time, it is possible after multiple spawning events that most or all of the fish within a given brood tank would contribute to a released population and that the contribution of each brood fish within a brood tank *could* be more-or-less equalized. Experiments designed to assess this possibility are currently underway. Relative to an individual release, the  $N_e$  estimated from a symmetric-contribution simulation (19.4) was not appreciably different from an optimal  $N_e$  based on a proportional-contribution simulation (20.8). Both were far larger than the  $N_e$  based on a random, asymmetric-contribution simulation (9.3), suggesting that over a limited time period the simplest approach to maximizing  $N_e$  of a release would be to utilize equal numbers of progeny from each brood tank.

A final point to note is that even if the optimal number of effective breeders from a given hatchery could be maximally approached during a release, the genetic risk of a supplementation program relative to reducing the effective size of the ‘wild’ population (Ryman and Laikre, 1991) might still exist, given that the number of adult red drum in TPWD hatcheries is roughly 100-125 individuals while the number of red drum adults in the northern Gulf of Mexico is in excess of three million (Nichols, 1988; Mitchell and Henwood, 1999; Turner et al., 2002). Tringali and Bert (1998) considered this in their treatise on red drum stock-enhancement in Florida but concluded there was no apparent risk because of the large size and apparent lack of geographic population structure among ‘wild’ red drum. They did suggest, however, that an adequate number of breeders and modest per-generation contributions should be used in red drum stock enhancement. However, red drum in the northern Gulf of Mexico are not necessarily

one large, panmictic population (Gold et al., 2001; Gold and Turner, 2002) and it is possible that a large release from a small number of breeders could impact 'local' effective size of a 'wild' population at least over a short period of time. Research to address this possibility also is ongoing.

## 5.2. *Heritability of early larval growth, juvenile growth rates, and cold tolerance*

Genetic management of breeding stocks in aquaculture is important to ensure long-term sustainable development (Chevassus et al., 2004). Implementing modern genetic management, however, generally requires pedigree information, which can be obtained through parentage assignment (O'Connell and Wright, 1997). Reliable pedigree information is critical to modern genetic management relative to estimating heritability, minimizing inbreeding in captive populations, and estimating effective population size (Blouin, 2003). Because of the difficulty in physically tagging fish during early life-history stages, family information (pedigree of an individual) can only be obtained either when families are reared separately or by assaying each individual progeny for polymorphic genetic markers and assigning parentage *a posteriori* based on the obtained genotypes (Norris et al., 2000; Vandeputte, 2003). The latter is preferred, as it permits progeny from multiple parents to be reared in 'common-garden' environments (O'Connell and Wright, 1997).

In this study, a total of four polymorphic microsatellites were used to assign progeny to their parents in a series of experiments, based on a common-garden design, to estimate genetic parameters and heritability for larval growth, juvenile growth rate, and cold tolerance. Estimating the genetic parameters and heritability of these traits is of

importance relative to a selective breeding program to improve performance and reduce operating costs. Increased growth rate of red drum could decrease duration of the rearing cycle, whereas increased cold tolerance could mitigate mortality in outdoor growing ponds during the winter. Progeny performance for early larval growth, juvenile growth rate, and cold tolerance was monitored and family (genetic) effects on these traits were assessed.

A family (genetic) effect was found to contribute significantly ( $P = 0.000$ ) to the variance in early larval growth (weight). The proportion of the family (genetic) variance to the overall phenotypic variance, however, was fairly low (3.7%) and corresponded to the estimate of heritability ( $h^2 = 0.07 \pm 0.03$ ) under the genetic model employed. Similar results (i.e., a relatively small genetic component to the overall phenotypic variance in early larval growth) also were found in experiments with channel catfish (Bean, 1977), (Henryon et al., 2002), and Nile tilapia (Tave and Smitherman, 1980).

Spawning-group effect also was found to contribute significantly ( $P = 0.000$ ) to the variance in early larval growth. The proportion of the phenotypic variance due to spawning-group effect was relatively high (30.5%) and was almost nine-fold greater than the proportion of the variance due to genetic (family) effect. This spawn effect likely stemmed in part from variation in spawning date across tanks during the two-week period and in part from ‘uncontrolled’ factors such as differences in environmental conditions among outside rearing ponds where larvae were held prior to assays. Variation in spawning and hatching time, leading to age difference among spawns, is



known to affect early larval growth rates, as is variation in food source in grow-out ponds (Wurts, 1981).

The significant genetic effect on early larval growth in red drum suggests that genetic selection for increased early larval growth in red drum could be possible and might be of interest to the TPWD stock-enhancement program given that more rapid larval growth might shorten the length of time between spawning and release, thereby potentially minimizing expenses in physical resources (e.g., ponds and/or fertilizer, et cetera) and personnel time. However, the relatively low estimate of the heritability suggests that genetic improvement likely would be slow. In addition, the estimate of heritability was derived from the full-sib family component of variance and thus was based on the assumption that the family variance was due only to additive genetic effects. The estimates may thus be biased upward because of possible non-additive genetic and maternal effects (see below). Consequently, improvement of early larval growth rate in red drum, relative to shortening the length of time between spawn and release, might be more effectively achieved by controlling non-genetic (i.e., environmental) factors.

A significant family (genetic) effect on growth rate of juvenile red drum was found at each of two time intervals ( $P = 0.001$  for the growth rate between 148 and 189 days post-hatching, and  $P = 0.006$  for growth rate between 190 and 208 days post-hatching). The proportion of the family (genetic) variance to the overall phenotypic variance was 25.8% and 10.1%, respectively, for the two time intervals and corresponded to the estimates of heritability ( $0.52 \pm 0.21$  and  $0.20 \pm 0.10$ , respectively) under the genetic model employed. Significant genetic effects (and corresponding estimates of

heritability) have been documented for juvenile growth in many other cultured fishes. Doupe and Lymbery (2005), for example, estimated the proportion of total phenotypic variance due to additive-genetic effects in juvenile growth of black bream (*Acanthopagrus butcheri*) to be 8.7%, with an estimated heritability of 0.17. Relatively high estimates of heritability for juvenile growth also have been reported in common carp ( $h^2 = 0.33 \pm 0.08$ , Vandeputte et al., 2004), channel catfish ( $h^2 = 0.28 \pm 0.85$ , Reagan, 1979), rainbow trout ( $h^2 = 0.32 \pm 0.08$ , Gall and Gross, 1978), chinook salmon ( $h^2 = 0.39 \pm 0.08$ , Winkelman and Peterson, 1994), and European sea bass ( $h^2 = 0.29 \pm 0.13$ , Saillant et al. 2005).

A significant ( $P = 0.000$ ) spawning-group effect was found at the first time interval (9.1% of the total phenotypic variance), but not at the second; whereas, a significant tank effect ( $P = 0.001$ ) was found at the second time interval (2.5% of the total phenotypic variance), but not at the first. The proportion of the total phenotypic variance due to spawn (first interval) and tank (second interval), however, was considerably smaller than the genetic effect due to family. The tank x spawn interaction effect was not significant at either time interval.

The relatively high heritability estimates found at the two time intervals suggests that genetic selection for increased juvenile growth rate in red drum could lead to a significant response. However, the estimates of heritability were generated under a full-sib model and thus may be biased upward because of possible non-additive genetic and/or maternal effects (see below). Estimates of heritability unbiased by these sources of phenotypic variation are clearly warranted. Increased juvenile growth rate might be

of interest to the TPWD stock-enhancement program if releases were to occur after a juvenile grow-out phase. More rapid juvenile growth rates would definitely be of interest to private red drum aquaculture where it generally takes about 2-3 years to grow fish to a marketable size of 2.5-3 pounds (Lutz, 1999).

Finally, a significant ( $P = 0.003$ ) family (genetic) effect was found to contribute to the phenotypic variance in juvenile cold tolerance. The proportion of the phenotypic variance due to the family effect was 14.9% and corresponded to the estimate of heritability ( $h^2 = 0.30 \pm 0.11$ ) under the genetic model employed. Heritability of cold tolerance has been studied previously only in Nile tilapia (*Oreochromis niloticus*) where both Behrends et al. (1996) and Charo-Karisa et al. (2005) reported heritability estimates of less than 10%. In addition, there are reports (Craig et al., 1995; Cnaani et al., 2000; Charo-Karisa et al., 2005) that the degree of tolerance to sub-optimal temperatures in fish is also dependent upon environmental effects, history, and nutritional status. In the present study, however, no significant tank or tank x family interaction effects were found.

The significant family (genetic) effect and the relatively high heritability for cold tolerance in juvenile red drum suggest that selection for increased cold tolerance in red drum could be effective. However, as was the case in the estimates of heritability for early larval growth and juvenile growth rate, the estimate of heritability for cold tolerance may be biased upward because of possible non-additive genetic and maternal effects. Increased thermal tolerance in juvenile red drum might be of interest to the TPWD stock-enhancement program as growth in outdoor rearing ponds might be

possible during the winter months (Davis, 1990). Increased thermal tolerance in juvenile red drum would definitely be of interest to private red drum aquaculture as poor growth and large mortality are now associated with over-wintering red drum in outdoor ponds (Lutz, 1999).

Several factors, viz., additive and non-additive (dominance and epistatic) genetic effects, maternal effects, and environment effects, potentially impact phenotypic variation, especially for traits such as growth (Su et al., 1996; Rye and Mao, 1998; Henryon et al., 2002) and thermal tolerance (Cnaani et al., 2000; Charo-Karisa et al., 2005). Unfortunately, the relatively small number of breeders (mating pairs) and the large variance in family size in each of the three experiments designed here to estimate heritability necessitated use of a full-sib (family) model to estimate genetic effects. The estimates of heritability derived from the family (genetic) variance component thus provided a 'biased' estimate of heritability in that additive-genetic, non-additive genetic, and maternal effects were included. This 'biased' estimate could provide a reasonable estimate of the additive-genetic component if dominance, epistatic, and maternal effects are minimal or negligible.

In general, non-additive genetic effects (dominance and epistasis effects) are difficult to estimate because of the large mating designs required (Varona and Misztal, 1999). In addition, the occurrence and magnitude of non-additive genetic effects on traits such as growth and thermal tolerance in fish are not well studied. Doupe and Lymbery (2005) did not find significant non-additive genetic effects on growth traits in juvenile black bream, while significant, non-additive genetic effects (dominance and/or

epistasis) on juvenile growth were found by Winkelman and Peterson (1994) and Rye and Mao (1998) in chinook salmon (*Oncorhynchus tshawytscha*) and Atlantic salmon (*Salmo salar*), respectively. Non-additive genetic effects (primarily dominance) also were hypothesized as a component of cold tolerance in Nile tilapia (Wohlfarth et al., 1983; Cnaani et al., 2000).

Although non-additive genetic effects are often considered to be negligible (Varona and Misztal, 1999), it is not possible to rule out non-additive genetic effects on growth and cold tolerance in juvenile red drum. Since the presence of significant, non-additive effects generates upwardly-biased estimates of heritability based on additive-genetic effects (Gjerde, 1986), heritability for growth and cold tolerance in red drum may be less than estimated here. Further study that utilizes a more robust experimental design is warranted.

One additional effect that needs to be considered relative to genetic management of breeding stocks is a maternal effect where the phenotype of an individual is a function of the genotype(s) or environment of its maternal parent (Falconer, 1965; Mousseau and Fox, 1998). Maternal effects may comprise a significant fraction of the phenotypic variance for a given trait among individuals at early life stages (Vandeputte et al., 2002) and have been shown to significantly effect early growth of fish (Lutz, 2001; Henryon et al., 2002; Vandeputte, 2003). While a maternal effect could not be estimated in this study, maternal effects on growth rates appear in general to decrease over time (Robinson and Luempert, 1984; Crandell and Gall, 1993; Doupe and Lymbery, 2005). The larger family (genetic) component observed during juvenile growth of red drum, as

compared to that observed during early larval growth, may indicate occurrence of a maternal effect during larval growth. Future experiments should examine this possibility.

### 5.3. *Test of Mendelian inheritance*

Microsatellite markers have been used extensively in fish research in studies of stock structure, parentage, kinship, and genome mapping (Liu and Cordes, 2004). In this study, a total of 31 microsatellite loci were tested individually for Mendelian segregation and in pairwise combinations for independent assortment, using two families generated from a single dam and a single sire. Segregation at 29 of the 31 microsatellites fit Mendelian expectations for autosomal loci, as each parental allele was found among progeny in expected proportions. Significant deviations from Mendelian expectations were observed at two of the microsatellites (*Soc* 201 and *Soc* 401). Segregation at both microsatellites, however, fit Mendelian expectations if a ‘null’ allele was assumed to be present in one of the parents scored initially as a homozygote.

Detection of null alleles is of more than passing interest as the failure to detect a null allele or alleles at co-dominant genetic markers leads to incorrectly scoring a heterozygote as a homozygote. This will confound allele-frequency estimates and generate overestimates of inbreeding in population-level studies (Li et al., 2003), as well as result in false exclusions in parentage studies (Pemberton et al., 1995). Unfortunately, it is not possible to unambiguously confirm presence of null alleles without either inheritance studies (Pyatskowit et al., 2001) such as done in this study or from direct sequencing to establish variation at the 3-prime end of a PCR priming site

(Callen et al., 1993). Detection of null alleles at both *Soc* 201 and *Soc* 401 will be useful in future experiments planned for our laboratory where attempts will be made to separate hatchery-raised red drum from ‘wild’ fish based on microsatellite genotypes.

Results from pairwise tests of independent assortment demonstrated that 20 of the 31 microsatellites could be placed into seven linkage groups. These results confirmed earlier work by O’Malley et al. (2003) where seven of the microsatellites had been assigned to three of the linkage groups based on development of PCR primers from the same genomic DNA clone. Additional linkage groups (containing two microsatellites each) inferred by O’Malley et al. (2003), but not tested in this study, increased the number of inferred linkage groups in red drum to nine, with a range of two – five (avg. = 2.78) microsatellites in each linkage group. The remaining 11 microsatellites tested in this study assorted independently from all other microsatellites, suggesting the possibility of 11 additional linkage groups. A point to note is that inferences regarding the number of linkage groups are constrained as markers may be on the same chromosome (and hence the same linkage group *sensu strictu*), yet be separated by more than 50 cM (centiMorgan) and display independent assortment (Griffiths, 1993).

The microsatellite linkage map generated in this study represents a beginning. Genetic maps have played a prominent role in many areas, including analysis of quantitative trait loci (QTLs), map-based cloning of genes, marker-assisted selection in breeding programs, and comparative genomics (Liu and Cordes, 2004). At present, linkage maps exist for a number of fish species, including zebrafish (Shimoda et al., 1999), medaka (Ohtsuka et al., 1999), rainbow trout (Sakamoto et al., 2000), Nile tilapia

(Kocher et al., 1998) and channel catfish (Waldbieser et al., 2001). In these species, highly polymorphic DNA markers such as RAPDs and AFLPs were used along with microsatellites to construct fine-scaled genetic linkage maps. For example, 2000 microsatellites were used in zebrafish to produce a linkage map with an average resolution of 1.2 cM and an average marker interval of 0.74 cM (Shimoda et al., 1999), while more than 112 AFLPs, 525 microsatellites and 21 gene-based markers were used in Nile tilapia to generate an estimated map length of about 2000 cM arranged in 22 major linkage groups (Kocher et al., 1998, 2001; Lee et al., 2005). The rationale for genome mapping in experimental models such as zebrafish and medaka is to pursue both biological and biomedical research; whereas in species used in aquaculture (e.g., Nile tilapia and channel catfish) the rationale is to increase the efficiency of selective breeding for genetically superior strains (Tong and Chu, 2002). Red drum fall into the latter category and are raised in aquaculture facilities in part for commercial sale (Gatlin, 2000) and in part for release into the 'wild' in order to supplement natural populations (McEachron et al., 1995). Given the demonstration in this study of a genetic component to early larval growth, juvenile growth rates, and thermal (cold) tolerance, a saturated genetic map for red drum ultimately could help identify specific genes associated with these traits.



## 6. SUMMARY

Hypervariable DNA markers (nuclear-encoded microsatellites) were employed to address three areas related to the stock-enhancement program of the Texas Parks and Wildlife Department (TPWD) and to red drum aquaculture. Three areas under study were as follows: (i) the genetic effective size ( $N_e$ ) of red drum spawning over a two-week period in nine brood tanks at a TPWD hatchery; (ii) the narrow-sense heritability of early-larval growth and growth rate and cold tolerance of juveniles, (iii) the Mendelian inheritance (segregation and independent assortment) of 31 nuclear-encoded microsatellites developed from a red drum genomic library. The maximum (expected)  $N_e$  over all nine brood tanks, assuming all tanks contributed equally to the offspring population, was 43.2. The observed  $N_e$  over all nine brood tanks, assuming all tanks contributed equally to offspring population, was 27.0. The estimate of  $N_e$  based on observed variation in family size was 19.4. Simulations where the number of offspring released per brood tank varied indicated that over a limited time period the simplest approach to maximizing  $N_e$  of a stock-enhancement release would be to utilize equal numbers of progeny from each brood tank. A family (genetic) effect was found to contribute significantly to the variance in early larval growth, juvenile growth rate, and cold tolerance. The proportion of the family (genetic) variance to the overall variance in early larval growth was fairly low (3.7%) and corresponded to an estimate of heritability ( $h^2$ ) of  $0.07 \pm 0.03$  under the genetic model employed. The proportion of the family (genetic) variance to the overall variance in juvenile growth rate was 25.8% and 10.1% at each of two growth intervals and corresponded to estimates of

heritability of  $0.52 \pm 0.21$  and  $0.20 \pm 0.10$ , respectively, under the genetic model employed. The proportion family (genetic) variance to the overall variance in cold tolerance was 14.9% and corresponded to an estimate of heritability of  $0.30 \pm 0.11$  under the genetic model employed. The relatively low estimate of heritability for early larval growth suggests that genetic improvement for this trait likely would be slow. The heritability estimates for juvenile growth rate and cold tolerance, alternatively, suggest that genetic selection these traits could be effective. Segregation at 29 of the 31 microsatellites fit Mendelian expectations for autosomal loci. Significant deviations from Mendelian expectations were observed at two of the microsatellites. Segregation at both microsatellites, however, fit Mendelian expectations if a 'null' allele was assumed to be present in one of the parents scored initially as a homozygote. Results from pairwise tests of independent assortment demonstrated that 20 of the 31 microsatellites could be placed into seven linkage groups. Additional linkage groups inferred from a prior study increased the number of inferred linkage groups in red drum to nine, with a range of two - five (avg. = 2.78) microsatellites in each linkage group. The remaining 11 microsatellites tested in this study assorted independently from all other microsatellites, suggesting the possibility of 11 additional linkage groups.

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## APPENDIX 1

Summary data 31 microsatellites used in the study. PCR primer sequences are forward (top) and reverse (bottom). Primers developed from a single clone, and presumably amplifying tightly linked microsatellites, are designated with the same letter. Repeat sequence indicates the repeat motif. Data are taken from Saillant et al. (2004).

Micro-satellite	PCR sequences (5'→3')	Repeat sequence	Annealing temperature	Number of alleles
<i>Soc 11</i>	GCCGAGTCACGAAGGAACAGAGAA TGTCGTCTCATCTATCTCCATCTC	(GA) <sub>11</sub>	62	14
<i>Soc 19</i>	GGGTACAATAAACAGACACAATA TTTGAAAATGTTCCCTGTGAATCAC	(GATA) <sub>16</sub>	58	21
<i>Soc 44</i>	GAGGGTGACGCTAACAGTTGA CACAGCTCCACTCTGATATG	(CA) <sub>22</sub> (GT) <sub>5</sub>	62	6
<i>Soc 60</i>	TCTATTGAAGCCTGTAAGTTAGTT CAAGGAAGGAGTGGGGAATGACAA	(AGG) <sub>8</sub>	56	6
<i>Soc 83</i>	TGCTGTAATTGAAAAGCAGTGTAC AGCGGAACTAGAATTGGTTTTATA	(TG) <sub>19</sub>	56	6
<i>Soc 85</i>	TTTTGGACCTACACTAGAGTAGC CGTGGGAGACTAGCGATGTAGAT	(AC) <sub>17</sub>	58	5
<i>Soc 99</i>	CACCCACTGACACACACATACAC GGAACCAATATGTCTGCCATGAT	(CA) <sub>29</sub>	62	12
<i>Soc 138</i>	CTGGAGCTTTTCCCTTTCTGT TGGGAGGAGAAGGCAGGAAGG	(TGTC) <sub>6</sub>	58	8
<i>Soc 140</i>	GGTGCAAACACAGCCATACAGT GCAAAATCGAAGACCGAGTTTAG	(CTGT) <sub>8</sub>	56	5
<i>Soc 156</i>	CCTCTCCTTTCTCCATCAGTGC AGCCCGGCTGTCATCTCCTGTA	(CCT) <sub>6</sub> (TCC) <sub>4</sub>	58	12
<i>Soc 201</i>	GGAGGAACTGATGAGGGCAGTGT GCACAACACACCTCGCTATATC	(CCT) <sub>6</sub>	58	4
<i>Soc 206</i>	GTTTCCACATCCCCCAACC AGTTTGGTCGCTTTAAAGGC	(GCAC)	58	4

<i>Soc</i> 243	GACGGGGATGCCATCTGC AATGCGAAAAAGACGAAACAGT	(CCT) <sub>9</sub>	56	6
<i>Soc</i> 400	TGCCATTGTCATTCTACAGAGC TTATAGTGGGGTGAGTGTTTGA	(CA) <sub>19</sub>	52	7
<i>Soc</i> 401	ACGTCTTAATCGGTCTCTGTCC ATCTCTGTGTGAAAGGAAAACA	(TG) <sub>14</sub>	52	6
<i>Soc</i> 402	CATATTTAACGAGCGACATAGC AAACAGATGAAGCACCTGGACT	(CA) <sub>20</sub>	52	5
<i>Soc</i> 404	AGACCCTTTTGTGATTTCATA ATGACTGCACCATTTCAAAAAG	(TG) <sub>23</sub>	52	9
<i>Soc</i> 407	AAAGTCTGCCTCTTACAGCTTC GAGTTAAAGCGTGTGCTAGTCC	(CA) <sub>13</sub>	56	6
<i>Soc</i> 410	GTACCAAGTCAGCCAGTGTCAG TCTCTGTGTCCCTCTGTGTTTG	(TG) <sub>17</sub>	56	7
<i>Soc</i> 412	CACAGAACTCAGCTCGAGACC AGGAAGAATGTACAAGGTGTTC	(AC) <sub>13</sub>	49	6
<i>Soc</i> 415 <sub>A</sub>	CTCAGCACCTCAGACATATGG CACAAGTTAAGTGGTATCGAGT	(TG) <sub>15</sub>	52	6
<i>Soc</i> 416 <sub>A</sub>	CTCGATACCACTTAACTTGT ATCGACATAATCTGGCACCA	(GA) <sub>38</sub>	49	6
<i>Soc</i> 417 <sub>A</sub>	CTTACGTGATAAAGTGTGGGTGA ATATGCCAGTAATCCACCGAAG	(AC) <sub>24</sub>	49	4
<i>Soc</i> 419	ATTTAGCCAACCTGCTCCGCTCA GAGTGCGTGGTGTAGGGGGGTA	(AC) <sub>20</sub>	56	6
<i>Soc</i> 423	GTCACCGCACCATGATGGAGAT TACCACTTACACTCAGCAGGTG	(CA) <sub>26</sub>	54	6
<i>Soc</i> 424	CACTCTTCATCCCTCACTCGTC TTCGATGGGTGACAGCGTCAGG	(CA) <sub>15</sub>	56	9
<i>Soc</i> 428	GACATCGCATTTGTCTACAGAGTCG AACTCCCAGTCATAATATCCCTTT	(TG) <sub>38</sub>	53	8
<i>Soc</i> 432 <sub>B</sub>	TTTAGGCTACGTCTGGAGGCACA GTGTGTTTGAGGGTCAGCGTAC	(AC) <sub>16</sub>	52	5
<i>Soc</i> 433 <sub>B</sub>	AGTACGCTGACCCTCAAACACA TTCTCTTGCCTCCTTTTCCCTGA	(TG) <sub>16</sub>	52	6

<i>Soc 444<sub>C</sub></i>	TGAACTAATCCAGCCACAGATG CACAGCCGATTAAAGAGAGGGAAT	(TG) <sub>17</sub>	52	3
<i>Soc 445<sub>C</sub></i>	ATACAAAGGGACTCTCATACTCTC TTTAAATCCCATTACAGCTTT	(TCC) <sub>10</sub>	52	7

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## APPENDIX 2

Multiplex panels for 31 microsatellites used in testing Mendelian segregation and independent assortment. Primer quantities (in picomols) and fluorescent labels (ABI dye) are given for finalized PCR cocktails. PCR primer sequences and allele size ranges for each microsatellite are given in Appendix I. Multiplex PCR protocol and annealing temperatures for each panel are shown in the far right column. Specific details may be found in Renshaw et al. (2005).

Panel	Microsatellite	Quantity	ABI dye	Range in allele size	Touchdown protocol
1	<i>Soc412</i>	4.3	HEX	102-168	Touchdown I
	<i>Soc416</i>	3.2	NED	141-181	55° - 49.5°
	<i>Soc417</i>	0.7	FAM	86-112	49°
	<i>Soc423</i>	0.6	FAM	172-208	
	<i>Soc428</i>	2.7	HEX	172-242	
	<i>Soc445</i>	35	FAM	134-166	
2	<i>Soc60</i>	1.7	FAM	151-163	Touchdown I
	<i>Soc140</i>	0.5	NED	132-144	59° - 53.5°
	<i>Soc201</i>	9	HEX	224-243	53°
	<i>Soc243</i>	2	FAM	94-106	
	<i>Soc419</i>	1.4	FAM	238-260	
3	<i>Soc19</i>	5	FAM	195-267	Touchdown I
	<i>Soc85</i>	2.3	FAM	80-122	60° - 54.5°
	<i>Soc138</i>	4.5	HEX	77-123	54°
	<i>Soc156</i>	0.4	FAM		
	<i>Soc 206</i>	0.8	NED	246-265	
	<i>Soc410</i>	2.7	FAM	306-344	
4	<i>Soc11</i>	1.1	FAM	217-240	Touchdown II
	<i>Soc83</i>	6	HEX	114-142	62°
	<i>Soc99</i>	4.5	NED	131-209	56°
	<i>Soc407</i>	2.5	FAM	139-157	54°
	<i>Soc424</i>	3.5	HEX	204-230	
5	<i>Soc400</i>	2.2	FAM	245-266	Touchdown I
	<i>Soc402</i>	2.5	HEX	134-164	57° - 51.5°
	<i>Soc404</i>	3.4	FAM	150-212	51°

	<i>Soc415</i>	2.7	HEX	187-235	
	<i>Soc432</i>	0.7	HEX	98-118	
6	<i>Soc44</i>	7	HEX	211-271	Touchdown II
	<i>Soc401</i>	3.7	HEX	174-206	56°
	<i>Soc433</i>	0.7	FAM	84-102	52°
	<i>Soc444</i>	1	HEX	161-165	50°

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### APPENDIX 3

Variation in family size per mating pair per spawn. Dates of spawning are in parentheses.

			Dam 1	Dam 2	Dam 3		Sires	
BB-1	Spawn 1 (4/13/2002)	Sire 1	0	0	0		0	
		Sire 2	0	0	123		123	
		Dams	0	0	123		123	
BB-2*	Spawn 1 (4/16/2002)	Sire 1	0	77	0	Dam 4	125	
		Dams	0	77	0	48	125	
	Spawn 2 (4/17/2002)	Sire 1	0	47	77	0	124	
		Dams	0	47	77	0	124	
	BB-7	Spawn 1 (4/12/2002)	Sire 1	61	1	59		121
			Sire 2	1	1	2		4
Dams			62	2	61		125	
BB-8	Spawn 1 (4/15/2002)	Sire 1	72	0	0		72	
		Sire 2	51	0	0		51	
		Dams	123	0	0		123	
	Spawn 2 (4/10/2002)	Sire 1	0	0	52		52	
		Sire 2	0	0	64		64	
		Dams	0	0	116		116	
	Spawn 3 (4/12/2002)	Sire 1	87	0	0		87	
		Sire 2	34	0	0		34	
		Dams	121	0	0		121	
	BB-11	Spawn 1 (4/22/2002)	Sire 1	32	10			42
			Sire 2	9	56			65
			Sire 3	1	17			18
			Dams	42	83			125
Spawn 2 (4/20/2002)		Sire 1	0	75			75	
		Sire 2	0	33			33	
		Sire 3	0	16			16	
Dams	0	124						

BB-12	Spawn 1 (4/19/2002)	Sire 1	Dam1 103	Dam 2 0	Dam 3 0	Sires 103
		Sire 2	20	0	0	20
		Dams	123	0	0	123
VB3-1	Spawn 1 (4/23/2002)	Sire 1	Dam 1 0	Dam 2 0	Dam 3 101	Sires 101
		Sire 2	0	0	10	10
		Dams	0	0	111	111
VB3-3	Spawn 1 (4/18/2002)	Sire 1	Dam 1 0	Dam 2 0	Dam 3 0	Sires 0
		Sire 2	0	0	124	124
		Dams	0	0	124	124
VB4-1	Spawn 1 (4/23/2002)	Sire 1	Dam 1 0	Dam 2 4	Dam 3 0	Sires 4
		Sire 2	0	13	108	121
		Dams	0	17	108	125

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\* One fish (Dam 4) in brood tank BB-2 was identified initially by TPWD personnel as a male; parentage analysis revealed this fish to be female. The fish identified as Dam 1 was identified initially by TPED as a female. This fish (Dam 1) was not involved in a spawning event, so could have been a male.

## APPENDIX 4

Variation in family size per mating pair per brood tank.

		Dam 1	Dam 2	Dam 3		Sires
BB-1	Sire 1	0	0	0		0
	Sire 2	0	0	123		123
	Dams	0	0	123		123
BB-2		Dam 1	Dam 2	Dam 3	Dam 4	Sires
	Sire 1	0	124	77	48	249
	Dams	0	124	77	48	249
BB-7		Dam 1	Dam 2	Dam 3		Sires
	Sire 1	61	1	59		121
	Sire 2	1	1	2		4
	Dams	62	2	61		125
BB-8		Dam 1	Dam 2	Dam 3		Sires
	Sire 1	159	0	52		211
	Sire 2	85	0	64		149
	Dams	244	0	116		360
BB-11		Dam1	Dam2			Sires
	Sire 1	32	85			117
	Sire 2	9	89			98
	Sire 3	1	33			34
	Dams	42	207			249
BB-12		Dam 1	Dam 2	Dam 3		Sires
	Sire 1	103	0	0		103
	Sire 2	20	0	0		20
	Dams	123	0	0		123
VB 3-1		Dam 1	Dam 2	Dam 3		Sires
	Sire 1	0	0	101		101
	Sire 2	0	0	10		10
	Dams	0	0	111		111
VB 3-3		Dam 1	Dam 2	Dam 3		Sires
	Sire 1			0		0
	Sire 2			124		124
	Dams			124		124



		Dam 1	Dam 2	Dam 3	Sires
VB4-1	Sire 1	0	4	0	4
	Sire 2	0	13	108	121
	Dams	0	17	108	125

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## APPENDIX 5

Genotypes (allele sizes) at each of four microsatellites (Soc 19, Soc 85, Soc 402 and Soc 428) for parents and progeny from spawning events in 2002 used to estimate heritability of early larval growth. Missing data are indicated by dashed lines.

<u>Brood tank</u>	<u>Spawn</u>	<u>Individual</u>	<u>Soc 19</u>	<u>Soc 85</u>	<u>Soc 402</u>	<u>Soc 428</u>
BB1	1	Dam 3	219/247	100/102	144/148	194/196
		Sire 2	239/247	98/106	138/148	214/216
		1-1-1	219/239	98/100	138/148	194/216
		1-1-2	219/239	102/106	144/148	196/216
		1-1-3	219/247	100/106	148/148	194/216
		1-1-4	247/247	98/100	144/148	196/216
		1-1-5	247/247	98/100	144/148	196/216
		1-1-6	219/239	102/106	144/148	196/216
		1-1-7	247/247	102/106	144/148	194/216
		1-1-8	239/247	98/100	144/148	196/216
		1-1-9	219/239	100/106	138/148	194/216
		1-1-10	219/247	100/106	138/144	196/216
		1-1-11	239/247	98/102	144/148	196/216
		1-1-12	239/247	100/106	138/144	194/216
		1-1-13	219/239	100/106	144/148	196/216
		1-1-14	247/247	100/106	148/148	196/216
		1-1-15	219/247	98/100	138/144	196/216
		1-1-16	219/247	98/100	138/148	196/216
		1-1-17	219/239	98/100	148/148	194/216
		1-1-18	247/247	102/106	138/144	194/216
		1-1-19	247/247	102/106	138/148	196/216
		1-1-20	219/247	102/106	138/144	196/216
		1-1-21	219/239	98/102	138/144	194/216
		1-1-22	247/247	98/102	138/148	194/216
		1-1-23	—	—	140/148	—
		1-1-24	219/247	98/102	138/144	194/216
		1-1-25	219/247	102/106	148/148	196/216
		1-1-26	239/247	98/100	138/144	196/216
		1-1-27	219/239	102/106	138/144	196/216
		1-1-28	219/247	100/106	148/148	194/216
		1-1-29	219/247	100/106	138/148	196/216
		1-1-30	239/247	100/106	148/148	196/216

1-1-31	247/247	98/102	144/148	194/216
1-1-32	247/247	98/102	138/144	194/216
1-1-33	219/239	98/100	138/144	196/216
1-1-34	219/247	100/106	148/148	196/216
1-1-35	219/239	100/106	138/144	196/216
1-1-36	219/247	98/100	138/144	196/216
1-1-37	247/247	102/106	138/144	196/216
1-1-38	247/247	98/100	138/144	196/216
1-1-39	239/247	102/106	144/148	194/216
1-1-40	219/247	102/106	148/148	194/216
1-1-41	247/247	100/106	138/148	196/216
1-1-42	247/247	100/106	138/144	194/216
1-1-43	239/247	98/100	138/148	194/216
1-1-44	247/247	100/106	—	194/216
1-1-45	219/239	98/102	144/148	196/216
1-1-46	239/247	98/100	148/148	194/216
1-1-47	219/239	100/106	144/148	196/216
1-1-48	219/239	98/102	148/148	194/216
1-1-49	219/239	98/100	138/144	196/216
1-1-50	219/247	102/106	148/148	194/216
1-1-51	219/239	98/100	138/144	196/216
1-1-52	219/247	98/100	148/148	194/216
1-1-53	219/247	98/102	148/148	196/216
1-1-54	219/247	100/106	148/148	196/216
1-1-55	219/247	100/106	148/148	194/216
1-1-56	219/247	102/106	144/148	194/216
1-1-57	247/247	98/100	138/144	194/216
1-1-58	239/247	98/100	148/148	194/216
1-1-59	219/239	102/106	138/148	196/216
1-1-60	219/239	102/106	148/148	194/216
1-1-61	239/247	98/100	138/148	194/216
1-1-62	219/239	100/106	138/148	196/216
1-1-63	219/239	100/106	138/148	194/216
1-1-64	219/239	98/100	148/148	194/216
1-1-65	219/247	102/106	148/148	196/216
1-1-66	219/247	102/106	138/144	196/216
1-1-67	219/239	98/102	144/148	196/216
1-1-68	239/247	100/106	138/148	196/216

1-1-69	219/247	98/100	144/148	194/216
1-1-70	219/239	100/106	144/148	194/216
1-1-71	219/239	102/106	148/148	194/216
1-1-72	247/247	98/102	148/148	196/216
1-1-73	219/247	102/106	144/148	196/216
1-1-74	247/247	98/100	138/148	194/216
1-1-75	247/247	100/106	148/148	196/216
1-1-76	239/247	98/100	138/148	196/216
1-1-77	247/247	98/102	144/148	196/216
1-1-78	219/239	98/100	138/144	196/216
1-1-79	219/247	102/106	148/148	194/216
1-1-80	239/247	102/106	144/148	196/216
1-1-81	239/247	102/106	138/148	194/216
1-1-82	219/247	98/102	138/148	196/216
1-1-83	239/247	98/100	144/148	194/216
1-1-84	219/247	100/106	148/148	196/216
1-1-85	239/247	102/106	138/148	196/216
1-1-86	219/239	98/102	138/148	196/216
1-1-87	219/239	102/106	144/148	196/216
1-1-88	219/247	102/106	138/148	194/216
1-1-89	247/247	100/106	138/144	194/216
1-1-90	219/247	98/100	—	196/216
1-1-91	219/239	100/106	144/148	194/216
1-1-92	211/215	100/114	146/152	200/204
1-1-93	219/247	98/102	138/148	194/216
1-1-94	239/247	100/106	138/144	196/216
1-1-95	239/247	98/102	144/148	196/216
1-1-96	239/247	100/106	148/148	194/216
1-1-97	247/247	102/106	144/148	194/216
1-1-98	239/247	98/102	144/148	194/216
1-1-99	219/239	100/106	148/148	194/216
1-1-100	247/247	98/102	144/148	196/216
1-1-101	239/247	100/106	138/148	194/216
1-1-102	239/247	98/102	138/144	194/216
1-1-103	219/239	98/102	138/148	194/216
1-1-104	239/247	102/106	144/148	194/216
1-1-105	219/247	102/106	144/148	194/216
1-1-106	239/247	98/100	138/144	194/216

		1-1-107	219/247	100/106	148/148	194/216
		1-1-108	247/247	100/106	138/144	194/216
		1-1-109	247/247	100/106	144/148	194/216
		1-1-110	239/247	98/102	138/148	194/216
		1-1-111	239/247	98/100	138/148	194/216
		1-1-112	239/247	100/106	144/148	194/216
		1-1-113	239/247	98/102	148/148	194/216
		1-1-114	239/247	98/100	138/144	196/216
		1-1-115	239/247	100/106	138/144	196/216
		1-1-116	219/247	102/106	144/148	194/216
		1-1-117	239/247	98/100	138/148	196/216
		1-1-118	247/247	100/106	138/148	196/216
		1-1-119	219/239	102/106	138/144	194/216
		1-1-120	247/247	102/106	138/148	196/216
		1-1-121	—	—	—	186/188
		1-1-122	239/247	98/100	138/148	194/216
		1-1-123	219/247	102/106	148/148	194/216
		1-1-124	247/247	100/106	138/144	194/216
		1-1-125	219/247	98/102	138/148	196/216
		1-1-126	219/247	98/102	138/148	194/216
<hr/>						
BB2	1	Dam 2	223/227	100/110	140/164	192/206
		Dam 4	223/235	80/106	148/152	188/224
		Sire 1	215/235	100/102	148/148	188/232
		2-1-1	223/235	102/110	150/164	188/206
		2-1-2	227/235	102/110	150/164	188/206
		2-1-3	223/235	100/100	150/164	188/206
		2-1-4	215/227	102/110	140/150	206/232
		2-1-5	227/235	100/100	150/164	192/232
		2-1-6	223/235	100/100	150/164	192/232
		2-1-7	235/235	100/106	150/152	188/188
		2-1-8	227/235	100/106	150/152	188/232
		2-1-9	215/227	100/102	140/150	188/192
		2-1-10	235/235	80/102	148/150	190/190
		2-1-11	235/235	80/102	150/152	188/232
		2-1-12	215/227	100/110	150/164	188/192
		2-1-13	215/227	100/100	150/164	188/206
		2-1-14	227/235	100/110	140/150	206/232
		2-1-15	215/223	102/106	150/152	188/188

2-1-16	215/235	100/106	150/152	224/232
2-1-17	215/227	100/100	150/164	206/232
2-1-18	215/223	80/102	150/152	188/188
2-1-19	215/223	100/106	150/152	188/188
2-1-20	223/235	100/100	150/164	192/232
2-1-21	215/223	100/100	150/164	192/232
2-1-22	223/235	100/100	150/164	188/206
2-1-23	215/223	100/106	148/150	224/232
2-1-24	215/223	100/110	150/164	188/206
2-1-25	215/227	102/110	150/164	206/232
2-1-26	215/227	100/102	150/164	206/232
2-1-27	215/227	100/110	140/150	188/192
2-1-28	215/227	100/100	140/150	188/206
2-1-29	227/235	100/100	140/150	192/232
2-1-30	215/223	100/100	140/150	206/232
2-1-31	215/235	100/106	148/150	188/188
2-1-32	223/235	80/100	148/150	188/188
2-1-33	215/215	100/100	150/164	188/192
2-1-34	227/235	100/100	150/164	188/206
2-1-35	215/223	100/100	140/150	188/192
2-1-36	215/223	100/100	150/164	206/232
2-1-37	235/235	100/106	150/152	224/232
2-1-38	223/235	100/106	150/152	188/232
2-1-39	215/235	100/106	148/150	224/232
2-1-40	227/235	102/110	140/150	188/206
2-1-41	215/223	110/110	150/164	188/206
2-1-42	223/235	102/110	140/150	188/206
2-1-43	215/227	100/100	150/164	206/232
2-1-44	215/227	100/100	140/150	192/232
2-1-45	215/223	100/100	140/150	206/232
2-1-46	215/227	102/110	150/164	188/206
2-1-47	235/235	100/106	150/152	188/224
2-1-48	215/223	80/102	150/152	188/224
2-1-49	223/235	102/110	140/150	188/206
2-1-50	223/235	100/102	140/150	206/232
2-1-51	215/223	80/102	148/150	224/232
2-1-52	223/235	80/100	150/152	188/232
2-1-53	215/235	100/106	148/150	188/188

2-1-54	215/223	80/100	150/152	188/232
2-1-55	215/223	100/100	140/150	192/232
2-1-56	235/235	102/106	150/152	188/232
2-1-57	227/235	100/100	150/164	206/232
2-1-58	215/235	100/106	148/150	188/232
2-1-59	223/235	100/102	150/164	188/192
2-1-60	227/235	——	——	——
2-1-61	215/227	100/100	140/150	188/192
2-1-62	235/235	102/106	148/150	224/232
2-1-63	227/235	102/106	150/164	192/232
2-1-64	223/235	80/100	148/150	224/232
2-1-65	215/223	100/102	140/150	188/192
2-1-66	227/235	100/100	140/150	188/192
2-1-67	223/235	102/110	140/150	188/192
2-1-68	227/235	102/110	140/150	188/192
2-1-69	215/227	100/110	140/150	206/232
2-1-70	227/235	100/100	150/164	192/232
2-1-71	227/235	102/110	150/164	188/192
2-1-72	223/235	80/100	148/150	188/224
2-1-73	223/235	102/106	148/150	224/232
2-1-74	235/235	100/106	150/152	188/188
2-1-75	227/235	102/110	150/164	188/206
2-1-76	223/235	100/102	150/164	192/232
2-1-77	235/235	100/106	148/150	224/232
2-1-78	227/235	102/110	140/150	188/206
2-1-79	227/235	100/110	150/164	188/206
2-1-80	227/235	102/110	140/150	192/232
2-1-81	215/235	80/102	150/152	224/232
2-1-82	227/235	100/110	150/164	188/192
2-1-83	215/223	100/106	150/152	188/232
2-1-84	215/223	102/106	148/150	224/232
2-1-85	235/235	80/100	148/150	188/224
2-1-86	223/235	102/106	148/150	188/232
2-1-87	215/227	100/102	140/150	192/232
2-1-88	215/235	80/100	148/150	188/224
2-1-89	215/223	80/102	150/152	224/232
2-1-90	215/223	100/106	148/150	224/232
2-1-91	215/223	100/102	150/150	188/192

		2-1-92	223/235	100/106	150/152	188/232
		2-1-93	227/235	100/110	150/164	206/232
		2-1-94	223/235	100/102	150/164	188/192
		2-1-95	235/235	100/106	150/152	188/232
		2-1-96	215/227	100/100	150/164	206/232
		2-1-97	235/235	102/106	148/150	224/232
		2-1-98	223/235	102/106	150/152	224/232
		2-1-99	215/223	100/102	150/164	188/192
		2-1-100	235/235	80/102	150/152	224/232
		2-1-101	215/235	80/100	148/150	188/224
		2-1-102	215/223	80/102	148/150	188/224
		2-1-103	215/223	100/102	140/150	188/206
		2-1-104	215/235	80/100	150/152	188/232
		2-1-105	215/227	100/100	150/164	188/206
		2-1-106	215/227	102/110	140/150	188/192
		2-1-107	227/235	102/110	150/164	192/232
		2-1-108	227/235	100/102	150/164	206/232
		2-1-109	227/235	100/102	150/164	192/232
		2-1-110	215/223	102/110	140/150	206/232
		2-1-111	215/223	102/110	140/150	188/192
		2-1-112	215/235	80/102	148/150	188/188
		2-1-113	235/235	80/102	150/152	224/232
		2-1-114	223/235	102/110	150/164	192/232
		2-1-115	227/235	100/100	150/164	188/192
		2-1-116	215/223	100/100	150/164	192/232
		2-1-117	223/235	100/100	150/164	188/206
		2-1-118	215/235	102/106	150/152	188/232
		2-1-119	227/235	100/100	140/150	206/232
		2-1-120	227/235	102/110	150/164	188/192
		2-1-121	215/227	102/110	150/164	206/232
		2-1-122	215/227	100/100	140/150	188/206
		2-1-123	215/227	102/110	150/164	188/206
		2-1-124	223/235	102/110	140/150	206/232
		2-1-125	215/223	80/102	150/152	188/232
BB2	2	Dam 2	223/227	100/110	140/164	192/206
		Dam 3	231/239	80/100	146/150	188/192
		Sire 1	215/235	100/102	148/148	188/232
		2-2-1	223/235	100/100	140/150	188/188



2-2-2	223/235	100/102	150/164	188/206
2-2-3	215/231	100/100	146/150	188/188
2-2-4	227/235	100/110	140/150	188/192
2-2-5	235/239	80/102	146/150	192/232
2-2-6	215/231	100/100	146/146	192/232
2-2-7	231/235	100/100	146/150	192/232
2-2-8	235/239	80/102	146/150	192/232
2-2-9	223/235	102/110	150/164	188/192
2-2-10	215/227	100/102	140/150	188/192
2-2-11	223/235	102/110	150/164	192/192
2-2-12	235/239	80/100	150/150	188/192
2-2-13	227/235	102/110	150/164	206/232
2-2-14	235/239	80/100	146/150	188/192
2-2-15	223/235	100/100	150/150	188/192
2-2-16	215/227	100/100	150/164	188/206
2-2-17	223/235	100/100	140/150	192/232
2-2-18	223/235	100/100	150/164	206/232
2-2-19	215/231	80/100	146/150	188/232
2-2-20	235/239	80/100	146/150	188/192
2-2-21	215/223	102/110	140/150	188/206
2-2-22	227/235	102/110	140/150	192/232
2-2-23	231/235	80/80	150/150	192/232
2-2-24	215/239	100/100	150/150	188/192
2-2-25	231/235	80/102	146/150	188/188
2-2-26	215/227	100/102	150/164	192/232
2-2-27	227/235	100/100	150/164	188/192
2-2-28	215/231	100/102	146/150	192/232
2-2-29	227/235	100/100	140/150	192/232
2-2-30	215/239	100/100	146/150	188/192
2-2-31	235/239	100/102	150/150	188/188
2-2-32	227/235	100/100	140/150	188/192
2-2-33	215/239	80/102	146/150	192/232
2-2-34	215/223	100/102	140/150	206/232
2-2-35	215/227	100/100	140/150	192/232
2-2-36	215/239	100/102	146/150	192/232
2-2-37	231/235	100/100	146/150	188/188
2-2-38	215/239	80/100	146/150	192/232
2-2-39	235/239	80/100	146/150	192/192

2-2-40	215/223	100/102	140/150	188/206
2-2-41	215/239	100/102	146/150	188/188
2-2-42	215/239	80/102	150/150	188/232
2-2-43	215/239	102/102	150/150	188/188
2-2-44	235/239	100/100	146/150	192/232
2-2-45	215/227	100/100	140/150	192/232
2-2-46	227/235	100/100	140/150	192/232
2-2-47	215/239	100/102	146/150	188/192
2-2-48	215/231	80/100	150/150	186/188
2-2-49	215/231	100/102	150/150	188/188
2-2-50	215/231	100/102	148/150	188/232
2-2-51	215/231	100/102	150/150	188/188
2-2-52	231/235	80/102	146/150	188/192
2-2-53	215/223	100/102	140/150	188/206
2-2-54	215/239	80/100	148/150	188/192
2-2-55	215/231	80/102	146/148	188/232
2-2-56	235/239	80/100	148/150	186/188
2-2-57	215/231	80/100	150/150	188/232
2-2-58	215/231	100/102	148/150	188/232
2-2-59	215/239	80/100	144/148	188/188
2-2-60	215/227	100/102	150/164	188/206
2-2-61	235/239	100/100	150/150	188/188
2-2-62	215/223	100/100	140/150	206/232
2-2-63	215/231	100/102	146/150	188/192
2-2-64	231/235	80/102	150/150	192/192
2-2-65	235/239	100/100	148/150	188/232
2-2-66	227/235	102/110	150/164	206/232
2-2-67	215/239	80/100	148/150	186/188
2-2-68	231/235	100/100	148/150	188/188
2-2-69	215/227	100/100	140/150	206/232
2-2-70	235/239	100/102	146/150	192/232
2-2-71	215/231	100/102	146/150	188/192
2-2-72	215/227	100/100	140/150	192/232
2-2-73	215/231	100/100	146/150	192/192
2-2-74	215/239	80/102	148/150	188/192
2-2-75	215/239	100/100	146/150	188/188
2-2-76	223/235	102/110	150/164	188/192
2-2-77	227/235	100/100	140/150	188/192

2-2-78	223/235	100/100	150/164	188/206
2-2-79	215/231	100/100	148/150	188/232
2-2-80	215/231	80/102	148/148	188/192
2-2-81	235/239	100/100	148/150	188/188
2-2-82	215/239	80/100	146/150	188/192
2-2-83	223/235	100/110	150/164	188/192
2-2-84	215/239	80/100	148/150	192/232
2-2-85	223/235	100/102	150/164	192/232
2-2-86	215/239	80/100	148/150	188/192
2-2-87	215/239	80/102	128/150	192/232
2-2-88	227/235	102/110	150/164	188/206
2-2-89	215/223	102/110	150/164	206/232
2-2-90	215/223	102/110	140/150	206/232
2-2-91	—	—	—	—
2-2-92	231/235	100/100	146/150	188/192
2-2-93	215/231	80/102	150/150	188/192
2-2-94	231/235	80/100	146/150	188/232
2-2-95	231/235	80/100	146/150	188/232
2-2-96	215/239	100/102	150/150	192/232
2-2-97	215/239	100/102	150/150	192/232
2-2-98	215/227	100/102	140/150	206/232
2-2-99	235/239	80/100	146/150	188/188
2-2-100	215/231	80/100	146/150	188/232
2-2-101	235/239	80/102	146/150	188/188
2-2-102	231/235	80/102	150/150	188/232
2-2-103	227/235	100/102	140/150	192/232
2-2-104	223/235	100/102	140/150	206/232
2-2-105	235/239	80/100	150/150	188/192
2-2-106	223/235	100/110	140/150	188/192
2-2-107	215/223	100/102	150/164	188/206
2-2-108	215/239	100/100	150/150	192/232
2-2-109	215/223	100/110	140/150	188/206
2-2-110	231/235	80/100	146/150	188/192
2-2-111	215/227	100/102	140/150	192/232
2-2-112	223/235	100/100	140/150	192/232
2-2-113	235/239	80/102	150/150	188/192
2-2-114	215/231	100/100	146/150	188/192
2-2-115	215/239	80/102	146/150	188/188

		2-2-116	215/231	80/102	150/150	188/188
		2-2-117	231/235	100/102	146/150	188/232
		2-2-118	235/239	100/100	150/150	188/192
		2-2-119	227/235	102/110	150/164	188/192
		2-2-120	231/235	100/102	146/150	188/192
		2-2-121	235/239	100/100	150/150	188/192
		2-2-122	215/223	100/102	140/150	188/192
		2-2-123	215/239	100/102	146/150	188/188
		2-2-124	227/235	100/100	140/150	192/232
		2-2-125	235/239	100/100	150/150	188/192
BB7	1	Dam 1	227/231	100/118	140/146	192/206
		Dam 2	215/255	102/102	140/148	184/236
		Dam 3	215/247	100/106	150/150	202/222
		Sire 1	219/231	104/106	140/146	188/200
		Sire 2	223/227	96/120	146/152	188/206
		7-1-1	219/247	104/106	140/150	188/202
		7-1-2	231/247	100/106	146/150	200/222
		7-1-3	215/231	104/106	140/150	200/222
		7-1-4	227/231	106/118	140/140	188/192
		7-1-5	219/227	100/104	146/146	188/192
		7-1-6	219/247	104/106	140/150	188/222
		7-1-7	219/247	100/106	140/150	200/222
		7-1-8	215/231	100/104	146/150	188/222
		7-1-9	215/219	100/104	140/150	200/202
		7-1-10	219/227	106/118	140/146	188/206
		7-1-11	219/227	100/106	140/140	188/206
		7-1-12	215/219	104/106	140/150	188/222
		7-1-13	219/247	104/106	140/150	188/222
		7-1-14	227/231	100/104	146/146	188/192
		7-1-15	227/231	106/118	140/146	200/206
		7-1-16	219/227	106/118	140/146	188/206
		7-1-17	219/247	100/104	146/150	188/202
		7-1-18	219/231	100/106	140/146	188/192
		7-1-19	215/231	104/106	146/150	200/222
		7-1-20	231/231	104/118	146/146	188/206
		7-1-21	231/231	106/118	140/146	188/192
		7-1-22	219/227	100/106	140/140	188/206
		7-1-23	231/247	100/106	140/150	188/222

7-1-24	219/247	100/106	140/150	200/222
7-1-25	227/231	106/118	140/146	188/206
7-1-26	227/231	104/118	140/140	200/206
7-1-27	219/227	104/118	146/146	188/192
7-1-28	219/247	104/106	140/150	188/222
7-1-29	231/247	100/106	146/150	200/222
7-1-30	231/231	104/118	140/146	200/206
7-1-31	219/247	104/106	140/150	200/202
7-1-32	219/227	100/104	140/146	188/192
7-1-33	227/231	96/100	146/152	188/192
7-1-34	227/231	100/106	140/146	192/200
7-1-35	215/231	104/106	140/150	200/222
7-1-36	219/247	100/106	146/150	200/202
7-1-37	215/219	100/104	140/150	200/222
7-1-38	219/227	100/106	140/146	188/206
7-1-39	219/227	104/118	140/146	200/206
7-1-40	219/231	104/118	140/140	188/206
7-1-41	219/247	100/104	146/150	188/222
7-1-42	231/231	106/118	140/146	188/192
7-1-43	215/231	100/106	140/150	188/202
7-1-44	215/219	100/104	146/150	188/222
7-1-45	219/231	100/104	146/146	188/206
7-1-46	231/231	104/118	140/140	200/206
7-1-47	219/231	104/118	140/146	188/192
7-1-48	219/227	100/106	140/146	192/200
7-1-49	219/231	106/118	140/146	192/200
7-1-50	223/247	100/120	150/152	202/206
7-1-51	219/231	104/118	140/140	188/192
7-1-52	219/247	106/106	146/150	188/202
7-1-53	219/247	106/106	146/150	188/222
7-1-54	231/231	104/118	140/140	188/192
7-1-55	227/231	100/106	140/140	188/206
7-1-56	215/219	104/106	146/150	188/222
7-1-57	227/231	100/104	140/146	188/206
7-1-58	231/231	100/106	140/146	188/206
7-1-59	219/247	104/106	140/150	200/222
7-1-60	219/247	100/104	140/150	188/202
7-1-61	219/231	100/104	140/146	188/206

7-1-62	227/231	106/118	140/146	200/206
7-1-63	219/231	106/118	146/146	188/206
7-1-64	227/231	106/118	146/146	200/206
7-1-65	219/227	104/118	146/146	192/200
7-1-66	219/231	100/104	140/140	200/206
7-1-67	215/231	106/106	146/150	200/222
7-1-68	227/247	96/106	150/152	188/222
7-1-69	231/231	106/118	146/146	192/200
7-1-70	219/247	100/104	140/150	188/202
7-1-71	227/231	100/104	140/146	188/206
7-1-72	215/219	106/106	140/150	188/202
7-1-73	219/231	106/118	146/146	200/206
7-1-74	219/231	104/118	146/146	192/200
7-1-75	215/231	100/104	146/150	200/222
7-1-76	219/227	100/104	140/140	188/206
7-1-77	215/219	100/106	140/150	200/202
7-1-78	215/219	100/106	146/150	200/222
7-1-79	231/247	100/104	146/150	200/222
7-1-80	227/231	104/118	140/146	188/206
7-1-81	219/247	100/106	140/150	188/202
7-1-82	231/247	106/106	146/150	200/202
7-1-83	219/255	102/104	146/148	188/236
7-1-84	219/247	100/106	146/150	188/202
7-1-85	227/231	100/106	140/146	188/206
7-1-86	231/231	104/118	140/146	188/206
7-1-87	215/231	104/106	140/150	200/202
7-1-88	227/231	100/104	140/140	188/192
7-1-89	227/231	100/106	140/146	192/200
7-1-90	231/247	100/106	140/150	200/222
7-1-91	219/247	106/106	140/150	188/222
7-1-92	227/231	104/118	140/146	188/206
7-1-93	231/247	104/106	140/150	188/222
7-1-94	219/247	100/104	140/150	200/222
7-1-95	219/247	104/106	140/150	188/202
7-1-96	219/231	104/118	146/146	200/206
7-1-97	231/247	104/106	140/150	188/222
7-1-98	227/231	106/118	146/146	188/206
7-1-99	215/231	106/106	140/150	200/222

			7-1-100	215/231	106/106	146/150	200/202
			7-1-101	231/231	100/104	146/146	188/192
			7-1-102	227/231	100/104	140/146	188/192
			7-1-103	219/227	100/104	140/146	188/206
			7-1-104	231/231	100/106	140/146	200/206
			7-1-105	231/231	104/118	140/146	188/192
			7-1-106	231/231	100/106	140/146	200/206
			7-1-107	227/231	100/106	140/146	192/200
			7-1-108	215/219	106/106	140/150	188/202
			7-1-109	215/231	104/106	146/150	200/202
			7-1-110	227/231	106/118	140/146	188/192
			7-1-111	215/231	104/106	140/150	200/202
			7-1-112	215/219	100/106	140/150	188/202
			7-1-113	219/247	100/106	146/150	200/202
			7-1-114	219/247	100/106	140/150	200/202
			7-1-115	219/247	106/106	140/150	188/222
			7-1-116	215/219	100/106	146/150	188/202
			7-1-117	219/247	100/104	146/150	188/222
			7-1-118	219/231	106/118	146/146	200/206
			7-1-119	227/255	96/102	148/152	184/206
			7-1-120	231/247	104/106	146/150	200/222
			7-1-121	219/247	100/104	146/150	200/202
			7-1-122	215/219	100/104	146/150	188/202
			7-1-123	219/247	106/106	140/150	188/222
			7-1-124	231/231	100/104	140/140	188/192
			7-1-125	231/231	100/104	146/146	188/206
BB8							
	1	Dam 1	215/215	100/114	146/152	190/204	
		Sire 1	227/227	94/104	138/148	188/194	
		Sire 2	211/243	100/108	140/146	190/200	
		8-1-1	211/215	108/114	140/152	188/190	
		8-1-2	215/243	100/100	140/152	190/200	
		8-1-3	215/227	94/100	138/146	190/194	
		8-1-4	211/215	100/100	146/152	190/190	
		8-1-5	215/227	100/104	148/152	190/194	
		8-1-6	211/215	100/108	146/152	190/190	
		8-1-7	215/227	94/114	148/152	188/204	
		8-1-8	215/243	100/114	146/152	190/190	
		8-1-9	211/215	100/114	140/152	200/204	

8-1-10	215/227	94/114	138/152	188/190
8-1-11	215/243	100/114	140/146	200/204
8-1-12	211/215	100/114	140/146	200/204
8-1-13	211/215	100/100	146/146	188/190
8-1-14	215/227	94/100	138/146	188/190
8-1-15	211/215	100/100	146/146	190/200
8-1-16	215/243	100/108	146/152	188/190
8-1-17	215/227	94/114	146/148	194/204
8-1-18	215/243	100/114	140/146	190/200
8-1-19	211/215	108/114	140/152	188/190
8-1-20	211/215	100/100	140/146	200/204
8-1-21	211/215	100/108	140/146	188/190
8-1-22	215/227	104/114	138/152	188/190
8-1-23	211/215	100/108	146/152	200/204
8-1-24	211/215	108/114	140/146	190/204
8-1-25	211/215	100/100	140/152	190/204
8-1-26	211/215	108/114	146/152	190/204
8-1-27	211/215	100/114	140/146	190/200
8-1-28	215/227	104/114	138/152	194/204
8-1-29	215/243	100/108	146/146	200/204
8-1-30	215/227	104/114	148/152	188/204
8-1-31	215/243	100/114	146/146	190/190
8-1-32	215/227	100/104	138/152	190/194
8-1-33	215/227	94/114	138/152	194/204
8-1-34	211/215	100/100	146/152	190/190
8-1-35	215/243	100/100	146/152	190/190
8-1-36	215/227	104/114	138/146	190/194
8-1-37	211/215	108/114	140/152	200/204
8-1-38	215/227	100/104	138/146	188/190
8-1-39	215/243	108/114	146/148	200/204
8-1-40	215/227	104/114	148/152	194/204
8-1-41	215/243	108/114	146/146	190/204
8-1-42	215/227	100/104	138/152	188/204
8-1-43	215/243	100/108	140/146	190/190
8-1-44	215/243	108/114	140/146	190/204
8-1-45	211/215	100/114	146/152	190/190
8-1-46	215/227	100/104	148/152	190/194
8-1-47	215/227	104/114	138/152	194/204



8-1-48	211/215	100/114	140/152	200/204
8-1-49	215/243	100/100	140/152	190/204
8-1-50	215/227	94/114	148/152	188/190
8-1-51	215/227	104/114	146/148	194/204
8-1-52	215/243	100/114	140/146	200/204
8-1-53	215/227	104/114	138/152	188/204
8-1-54	215/243	100/100	140/152	190/204
8-1-55	215/227	100/104	138/146	190/194
8-1-56	215/227	94/114	148/152	190/194
8-1-57	215/227	104/114	146/148	190/194
8-1-58	215/227	94/100	138/152	194/204
8-1-59	215/243	100/108	146/146	188/190
8-1-60	215/243	100/114	140/146	200/204
8-1-61	211/215	100/100	140/146	190/190
8-1-62	215/227	94/100	148/152	190/194
8-1-63	215/243	100/114	140/152	190/204
8-1-64	215/227	104/114	146/148	194/204
8-1-65	215/243	100/100	140/146	200/204
8-1-66	215/227	94/114	146/148	194/204
8-1-67	215/243	100/114	146/152	190/200
8-1-68	215/227	104/114	146/148	194/204
8-1-69	215/243	100/100	140/146	200/204
8-1-70	215/227	94/100	138/152	188/190
8-1-71	215/227	94/100	148/152	190/194
8-1-72	215/227	104/114	148/152	190/194
8-1-73	215/227	100/104	148/152	188/204
8-1-74	215/243	100/100	146/152	190/204
8-1-75	215/227	94/100	148/152	190/194
8-1-76	211/215	100/108	140/146	190/190
8-1-77	211/215	100/100	140/146	190/200
8-1-78	211/215	100/114	146/152	200/204
8-1-79	215/227	104/114	146/148	188/204
8-1-80	211/215	100/114	146/152	190/204
8-1-81	215/243	108/114	146/152	200/204
8-1-82	211/215	108/114	146/146	188/190
8-1-83	211/215	108/114	140/152	190/190
8-1-84	215/227	94/100	146/148	190/190
8-1-85	215/243	100/114	146/146	188/190

8-1-86	215/227	94/114	138/152	190/194
8-1-87	215/243	100/100	146/152	190/200
8-1-88	——	——	——	——
8-1-89	211/215	100/114	140/152	190/200
8-1-90	215/243	100/114	146/152	190/204
8-1-91	——	——	——	——
8-1-92	215/243	100/100	146/146	190/200
8-1-93	215/227	94/100	138/152	188/204
8-1-94	215/243	100/108	140/146	190/204
8-1-95	215/243	100/108	146/146	190/204
8-1-96	215/227	104/114	146/148	190/194
8-1-97	215/227	94/100	148/152	188/204
8-1-98	211/215	108/114	140/146	190/200
8-1-99	211/215	100/100	146/152	200/204
8-1-100	211/215	100/100	140/152	200/204
8-1-101	215/227	104/114	148/152	190/194
8-1-102	215/227	94/114	146/146	190/194
8-1-103	215/227	94/100	146/146	188/188
8-1-104	215/243	100/100	140/152	190/204
8-1-105	215/227	94/100	138/152	188/190
8-1-106	211/215	108/114	140/146	190/204
8-1-107	211/215	100/114	146/146	190/204
8-1-108	215/243	100/100	146/152	190/200
8-1-109	215/243	100/114	140/146	190/200
8-1-110	211/215	100/108	146/146	188/190
8-1-111	215/243	108/114	146/152	190/200
8-1-112	215/227	94/114	148/152	188/190
8-1-113	211/215	100/114	140/146	190/190
8-1-114	211/215	108/114	146/152	190/200
8-1-115	211/215	100/100	140/146	190/190
8-1-116	215/227	104/114	138/152	190/194
8-1-117	211/215	100/108	140/146	190/200
8-1-118	215/227	100/104	138/146	188/204
8-1-119	215/227	100/104	138/146	190/194
8-1-120	215/227	94/100	138/146	188/204
8-1-121	215/227	94/100	138/152	188/190
8-1-122	215/227	100/104	146/146	188/204
8-1-123	211/215	108/114	146/146	188/190

		8-1-124	215/227	104/114	148/152	192/194
		8-1-125	215/243	108/114	146/152	200/204
BB8	2	Dam 3	211/223	100/102	140/148	190/200
		Sire 1	227/227	94/104	138/148	188/194
		Sire 2	211/243	100/108	140/146	190/200
		8-2-1	——	80/102	——	——
		8-2-2	211/227	94/100	138/148	188/190
		8-2-3	——	——	140/148	190/190
		8-2-4	211/223	100/102	140/148	190/200
		8-2-5	211/223	102/108	140/140	190/200
		8-2-6	211/223	100/100	140/140	190/190
		8-2-7	211/227	94/100	138/148	190/194
		8-2-8	211/243	100/100	140/140	200/200
		8-2-9	211/211	102/108	140/146	190/190
		8-2-10	211/243	102/108	140/140	200/200
		8-2-11	211/227	100/104	138/140	188/190
		8-2-12	211/211	100/100	146/146	190/200
		8-2-13	211/227	94/102	140/148	188/190
		8-2-14	211/223	100/100	140/148	190/200
		8-2-15	211/243	102/108	146/148	200/200
		8-2-16	223/227	102/104	140/148	194/200
		8-2-17	211/211	100/100	140/146	200/200
		8-2-18	223/243	100/100	146/146	200/200
		8-2-19	211/243	102/108	140/140	190/200
		8-2-20	211/227	94/102	148/148	194/200
		8-2-21	211/211	102/108	140/146	190/200
		8-2-22	223/227	102/102	138/140	188/200
		8-2-23	223/243	102/108	140/140	190/190
		8-2-24	223/227	102/104	138/140	190/194
		8-2-25	223/243	100/100	140/146	190/200
		8-2-26	223/227	94/100	138/140	188/190
		8-2-27	211/227	102/104	148/148	190/194
		8-2-28	223/227	102/102	148/148	190/194
		8-2-29	211/223	102/108	146/148	200/200
		8-2-30	211/227	94/100	138/148	194/200
		8-2-31	223/227	94/102	138/148	194/200
		8-2-32	211/227	94/100	138/140	194/200
		8-2-33	223/227	102/102	140/148	188/190

8-2-34	211/227	102/102	138/140	190/194
8-2-35	211/223	100/100	140/146	190/190
8-2-36	223/227	100/104	140/148	194/200
8-2-37	223/243	100/102	140/148	200/200
8-2-38	211/227	102/104	140/148	194/200
8-2-39	——	——	——	——
8-2-40	211/211	100/100	140/148	190/190
8-2-41	211/243	100/100	140/140	190/200
8-2-42	223/227	94/100	140/148	190/194
8-2-43	211/227	94/102	148/148	188/200
8-2-44	211/223	100/102	140/148	190/200
8-2-45	211/223	102/108	140/140	190/200
8-2-46	211/227	94/102	138/148	190/194
8-2-47	223/227	94/100	140/148	188/190
8-2-48	211/227	94/102	138/140	194/200
8-2-49	211/243	100/108	140/140	190/200
8-2-50	223/227	100/104	138/148	190/194
8-2-51	211/223	99/99	146/148	190/200
8-2-52	211/227	94/102	138/148	188/200
8-2-53	223/243	100/100	140/148	200/200
8-2-54	223/227	94/100	138/148	190/194
8-2-55	211/223	100/108	140/140	200/200
8-2-56	211/227	94/100	148/148	194/200
8-2-57	211/227	100/104	138/140	188/190
8-2-58	223/243	102/108	140/146	190/190
8-2-59	211/223	100/100	140/148	190/200
8-2-60	211/227	94/102	138/140	188/200
8-2-61	223/227	94/102	148/148	194/200
8-2-62	211/243	100/100	140/140	190/190
8-2-63	223/227	94/100	138/140	194/200
8-2-64	211/243	100/102	146/148	190/200
8-2-65	223/227	94/100	138/148	190/194
8-2-66	211/227	100/104	148/148	194/200
8-2-67	211/227	100/104	140/148	188/200
8-2-68	223/243	100/102	140/148	190/200
8-2-69	223/243	100/108	140/148	190/200
8-2-70	211/223	100/100	140/140	190/200
8-2-71	211/211	102/108	140/146	190/190

8-2-72	211/243	100/108	146/148	190/200
8-2-73	223/227	94/102	148/148	190/194
8-2-74	223/227	100/104	138/148	194/200
8-2-75	211/211	100/108	146/148	190/190
8-2-76	223/243	102/108	140/148	190/190
8-2-77	211/223	100/108	140/148	190/200
8-2-78	223/227	94/102	138/140	190/194
8-2-79	211/227	94/100	138/140	188/190
8-2-80	211/223	100/108	140/140	190/190
8-2-81	211/243	100/102	146/148	190/190
8-2-82	223/243	102/108	140/148	190/190
8-2-83	223/227	94/100	148/148	194/200
8-2-84	223/227	94/100	138/148	190/194
8-2-85	223/243	100/100	140/148	190/190
8-2-86	211/227	102/104	148/148	190/194
8-2-87	223/227	94/102	148/148	188/190
8-2-88	223/227	94/102	148/148	194/200
8-2-89	211/223	100/100	140/148	200/200
8-2-90	211/227	100/104	138/148	188/190
8-2-91	211/243	100/108	140/146	190/200
8-2-92	223/227	94/102	140/148	188/200
8-2-93	223/227	100/104	140/148	188/190
8-2-94	223/227	100/104	148/148	188/200
8-2-95	211/227	100/104	140/148	194/200
8-2-96	211/223	102/108	146/148	190/200
8-2-97	223/227	94/102	138/148	188/200
8-2-98	211/227	94/102	140/148	190/194
8-2-99	223/227	102/104	140/148	190/194
8-2-100	223/227	100/104	140/148	190/194
8-2-101	223/227	94/102	138/140	188/190
8-2-102	223/243	100/100	140/146	190/190
8-2-103	223/243	100/102	140/148	190/200
8-2-104	223/227	102/104	148/148	188/200
8-2-105	211/227	94/100	138/148	194/200
8-2-106	211/211	100/100	140/146	190/200
8-2-107	211/211	100/102	140/140	190/190
8-2-108	211/243	102/108	140/148	190/200
8-2-109	223/227	100/104	138/148	188/190

		8-2-110	223/227	102/104	138/148	190/194
		8-2-111	211/227	94/102	140/148	194/200
		8-2-112	223/227	102/104	148/148	188/200
		8-2-113	223/227	94/102	138/140	188/190
		8-2-114	211/227	100/104	138/148	188/200
		8-2-115	223/227	102/104	148/148	194/200
		8-2-116	211/243	100/102	140/140	190/200
		8-2-117	223/227	94/102	138/140	190/194
		8-2-118	211/223	100/102	140/140	190/200
		8-2-119	211/243	100/102	140/146	190/200
		8-2-120	223/227	94/102	140/148	188/190
		8-2-121	211/223	100/108	140/148	190/190
		8-2-122	223/243	102/108	140/148	190/190
		8-2-123	211/227	94/102	140/148	194/200
		8-2-124	223/227	94/102	138/140	188/200
		8-2-125	223/227	94/100	138/140	188/200
BB8	3	Dam 1	215/215	100/114	146/152	190/204
		Sire 1	227/227	94/104	138/148	188/194
		Sire 2	211/243	100/108	140/146	190/200
		8-3-1	215/243	100/100	140/146	200/204
		8-3-2	215/227	104/114	138/152	188/204
		8-3-3	215/227	100/104	138/146	188/190
		8-3-4	215/227	100/104	138/146	188/204
		8-3-5	215/227	94/100	148/152	194/204
		8-3-6	215/243	100/108	146/152	190/204
		8-3-7	215/243	100/100	146/146	200/204
		8-3-8	215/243	100/108	146/146	190/190
		8-3-9	215/227	94/100	138/146	194/204
		8-3-10	211/215	108/114	140/146	192/192
		8-3-11	211/215	100/114	146/152	190/190
		8-3-12	215/227	100/104	138/146	188/204
		8-3-13	211/215	100/108	140/152	190/204
		8-3-14	—	—	—	—
		8-3-15	211/215	100/108	146/146	200/204
		8-3-16	215/243	100/100	146/146	190/204
		8-3-17	215/243	100/100	146/152	200/204
		8-3-18	215/243	108/114	146/146	190/200
		8-3-19	215/227	104/114	146/148	190/194

8-3-20	211/215	108/114	140/152	190/204
8-3-21	215/243	108/114	146/152	200/204
8-3-22	211/215	108/114	140/152	190/200
8-3-23	215/227	104/114	138/146	188/204
8-3-24	215/243	100/100	146/152	190/200
8-3-25	215/227	94/100	138/146	188/190
8-3-26	211/215	100/108	140/152	190/190
8-3-27	215/227	104/114	148/152	188/204
8-3-28	215/243	108/114	146/146	190/190
8-3-29	215/243	100/114	146/146	190/204
8-3-30	215/227	100/104	146/148	188/190
8-3-31	215/243	100/108	140/152	190/204
8-3-32	215/243	100/114	146/152	190/200
8-3-33	215/243	100/100	140/152	200/204
8-3-34	215/227	94/100	138/152	190/194
8-3-35	211/215	100/108	146/152	190/190
8-3-36	215/227	94/114	146/148	188/204
8-3-37	211/215	108/114	140/152	190/204
8-3-38	215/243	108/114	146/146	190/190
8-3-39	211/215	100/108	146/152	190/190
8-3-40	215/243	100/114	146/152	190/200
8-3-41	215/243	100/108	146/152	190/204
8-3-42	211/215	100/100	146/152	190/200
8-3-43	215/227	104/114	138/152	188/204
8-3-44	215/227	94/100	146/148	188/190
8-3-45	215/243	100/100	140/152	190/200
8-3-46	215/243	108/114	146/152	190/204
8-3-47	215/243	100/100	140/146	190/204
8-3-48	215/243	100/100	140/152	190/200
8-3-49	215/227	104/114	148/152	190/194
8-3-50	215/227	104/114	146/148	194/204
8-3-51	215/243	100/108	140/152	190/200
8-3-52	215/227	94/100	138/152	190/194
8-3-53	215/227	100/104	138/146	190/194
8-3-54	211/215	100/108	146/152	190/204
8-3-55	211/215	100/108	140/146	190/200
8-3-56	215/243	100/108	140/152	190/204
8-3-57	215/243	100/100	140/152	190/200

8-3-58	215/227	94/114	138/152	194/204
8-3-59	215/243	108/114	146/152	190/200
8-3-60	211/215	100/108	146/152	190/200
8-3-61	211/215	108/114	146/152	190/200
8-3-62	211/215	108/114	140/146	190/190
8-3-63	211/215	100/108	146/146	190/204
8-3-64	211/215	100/108	140/146	190/204
8-3-65	215/243	108/114	146/152	190/204
8-3-66	211/215	100/100	146/152	200/204
8-3-67	211/215	100/100	146/146	190/190
8-3-68	215/227	94/100	138/146	194/204
8-3-69	215/227	104/114	148/152	188/190
8-3-70	215/227	94/100	148/152	190/194
8-3-71	211/215	100/108	140/146	190/204
8-3-72	211/215	100/114	140/152	190/190
8-3-73	215/243	108/114	140/146	190/200
8-3-74	215/243	108/114	140/152	190/200
8-3-75	216/243	100/100	146/152	190/204
8-3-76	211/215	100/114	146/146	190/190
8-3-77	215/243	100/114	146/146	190/204
8-3-78	215/243	100/108	140/146	190/204
8-3-79	215/227	104/114	138/152	194/204
8-3-80	215/243	100/114	146/152	200/204
8-3-81	215/227	100/104	138/146	188/204
8-3-82	215/243	100/100	140/146	190/200
8-3-83	211/215	100/108	146/146	200/204
8-3-84	215/243	100/108	144/146	190/190
8-3-85	215/243	100/100	146/152	190/200
8-3-86	215/227	100/104	138/152	190/194
8-3-87	215/243	108/114	140/152	190/190
8-3-88	215/243	100/114	140/146	188/190
8-3-89	215/227	94/100	148/152	186/188
8-3-90	215/227	94/114	138/152	190/194
8-3-91	—	—	—	—
8-3-92	215/243	108/114	140/152	188/190
8-3-93	211/215	108/114	140/146	200/204
8-3-94	211/215	100/114	146/146	190/200
8-3-95	211/215	100/108	140/152	200/204



		8-3-96	215/243	108/114	146/146	200/204
		8-3-97	215/243	108/114	140/146	188/190
		8-3-98	215/243	108/114	140/146	188/190
		8-3-99	211/215	100/114	140/146	190/200
		8-3-100	215/243	100/100	146/152	190/204
		8-3-101	215/227	94/100	138/152	190/194
		8-3-102	211/215	100/100	140/146	190/200
		8-3-103	215/227	100/104	138/152	188/190
		8-3-104	—	—	—	—
		8-3-105	215/243	100/114	146/152	190/204
		8-3-106	211/215	100/114	146/146	190/200
		8-3-107	211/215	108/114	140/152	200/204
		8-3-108	215/227	100/104	146/146	188/204
		8-3-109	215/243	100/108	146/146	200/204
		8-3-110	215/227	94/114	148/152	194/204
		8-3-111	215/227	94/114	138/152	188/204
		8-3-112	215/243	108/114	146/146	200/204
		8-3-113	—	—	—	—
		8-3-114	211/215	100/100	146/152	200/204
		8-3-115	211/215	100/114	146/146	200/204
		8-3-116	211/215	108/114	146/146	200/204
		8-3-117	211/215	100/100	140/146	190/200
		8-3-118	215/243	100/114	140/146	188/190
		8-3-119	211/215	100/114	146/146	190/200
		8-3-120	211/215	100/108	146/152	190/190
		8-3-121	211/215	100/100	146/146	188/190
		8-3-122	215/243	108/114	140/152	190/204
		8-3-123	211/215	100/100	146/146	190/204
		8-3-124	215/227	100/104	146/148	188/204
		8-3-125	215/243	100/100	146/146	190/190
BB11	1	Dam 1	219/231	104/108	148/148	204/208
		Dam 2	195/215	108/118	144/150	174/228
		Sire 1	219/231	96/102	150/154	174/236
		Sire 2	219/227	102/108	152/152	206/216
		Sire 3	235/243	100/110	138/146	196/232
		11-1-1	231/231	96/104	150/154	174/204
		11-1-2	219/235	108/110	140/150	204/232
		11-1-3	219/231	96/104	150/150	174/208

11-1-4	231/231	102/108	150/150	204/236
11-1-5	215/227	102/118	144/154	206/228
11-1-6	195/227	102/108	150/154	206/228
11-1-7	219/219	104/108	150/152	204/216
11-1-8	231/247	102/108	150/150	174/208
11-1-9	219/231	102/108	150/150	208/236
11-1-10	215/227	108/108	150/152	174/216
11-1-11	219/247	96/104	150/154	204/236
11-1-12	215/235	100/118	144/146	174/196
11-1-13	219/219	102/104	150/152	204/206
11-1-14	231/231	102/108	150/154	208/236
11-1-15	219/231	102/108	150/150	208/236
11-1-16	219/247	96/108	150/154	208/236
11-1-17	231/243	104/110	146/150	204/232
11-1-18	231/235	100/104	146/150	196/208
11-1-19	231/231	102/104	150/150	208/236
11-1-20	231/231	96/104	150/154	208/236
11-1-21	219/243	100/104	140/150	208/232
11-1-22	215/219	108/118	150/152	206/228
11-1-23	219/247	102/104	150/154	204/236
11-1-24	231/247	102/104	150/154	204/236
11-1-25	231/247	96/108	150/150	174/208
11-1-26	231/247	96/108	150/154	174/204
11-1-27	215/227	108/108	150/152	216/228
11-1-28	195/247	96/118	144/150	174/174
11-1-29	231/231	96/108	150/154	174/208
11-1-30	219/235	100/104	140/150	204/232
11-1-31	219/235	108/110	140/150	204/232
11-1-32	219/247	102/108	150/154	208/236
11-1-33	231/247	102/108	150/154	174/208
11-1-34	231/247	96/108	150/154	208/236
11-1-35	195/227	102/118	144/152	206/228
11-1-36	219/247	102/108	150/150	174/208
11-1-37	219/227	108/108	150/152	204/206
11-1-38	219/231	102/108	150/150	204/236
11-1-39	219/231	96/108	150/154	174/208
11-1-40	195/219	102/108	144/152	174/206
11-1-41	219/231	102/108	150/150	174/208

11-1-42	195/219	108/108	144/152	144/152
11-1-43	231/235	104/110	140/150	204/232
11-1-44	219/243	108/110	146/150	208/232
11-1-45	215/247	96/118	144/154	174/174
11-1-46	195/247	96/108	150/154	228/236
11-1-47	215/247	96/108	144/150	174/228
11-1-48	227/231	104/108	150/152	204/206
11-1-49	215/219	102/108	150/154	174/206
11-1-50	219/231	102/108	150/150	174/208
11-1-51	219/231	96/108	150/150	208/236
11-1-52	219/247	96/108	150/154	174/208
11-1-53	215/227	108/118	150/154	216/228
11-1-54	231/231	96/108	150/154	174/208
11-1-55	219/227	104/108	150/152	204/206
11-1-56	219/231	102/108	150/154	174/208
11-1-57	231/247	102/108	150/154	208/236
11-1-58	215/227	102/118	144/152	206/228
11-1-59	195/227	102/108	144/152	174/216
11-1-60	215/219	108/108	150/154	174/206
11-1-61	195/219	102/118	144/154	174/206
11-1-62	195/227	102/108	150/152	206/228
11-1-63	231/231	102/104	150/150	174/208
11-1-64	219/231	96/104	150/154	204/236
11-1-65	219/247	102/104	150/150	208/236
11-1-66	195/227	108/118	144/154	174/206
11-1-67	219/243	104/110	140/150	204/232
11-1-68	219/247	102/108	150/154	204/236
11-1-69	231/247	96/104	150/154	174/204
11-1-70	219/247	96/104	150/154	174/204
11-1-71	231/247	96/104	150/154	204/236
11-1-72	195/227	102/108	150/152	206/228
11-1-73	219/247	96/108	150/150	174/208
11-1-74	219/247	96/108	150/154	174/208
11-1-75	231/231	102/108	150/154	208/236
11-1-76	219/231	108/108	150/152	206/208
11-1-77	231/247	96/104	150/150	204/236
11-1-78	219/231	96/104	150/150	174/204
11-1-79	219/247	96/104	150/154	174/208

11-1-80	215/227	102/108	150/154	206/228
11-1-81	219/243	100/108	140/150	204/232
11-1-82	231/243	104/110	140/150	208/232
11-1-83	215/227	102/118	150/154	174/216
11-1-84	195/215	108/108	144/152	216/228
11-1-85	195/247	102/118	150/150	174/174
11-1-86	195/231	102/104	150/150	204/236
11-1-87	231/231	102/118	144/150	174/174
11-1-88	195/215	102/108	150/154	216/228
11-1-89	219/235	100/104	140/150	196/204
11-1-90	215/227	102/108	144/152	174/216
11-1-91	231/231	102/104	150/154	174/204
11-1-92	231/235	104/110	140/150	196/208
11-1-93	231/235	104/110	140/150	196/208
11-1-94	231/235	108/108	140/150	208/232
11-1-95	215/219	108/108	144/154	206/228
11-1-96	219/231	96/104	150/150	174/208
11-1-97	195/231	102/108	150/150	174/228
11-1-98	195/219	108/118	150/154	174/216
11-1-99	231/247	96/108	150/150	174/208
11-1-100	219/231	96/108	150/154	174/208
11-1-101	231/235	100/104	146/150	208/232
11-1-102	215/227	108/118	150/154	174/216
11-1-103	195/227	102/108	150/154	174/206
11-1-104	219/219	102/104	150/154	204/216
11-1-105	195/219	102/108	150/152	206/228
11-1-106	227/231	108/108	150/152	204/206
11-1-107	195/247	102/118	150/150	174/174
11-1-108	231/247	102/104	150/150	174/204
11-1-109	195/219	108/118	144/152	174/206
11-1-110	231/247	96/104	150/154	208/236
11-1-111	215/219	108/108	150/152	174/206
11-1-112	195/219	108/118	150/152	174/206
11-1-113	219/247	96/108	150/154	174/204
11-1-114	227/231	102/104	150/152	208/216
11-1-115	195/231	102/108	150/150	174/174
11-1-116	227/231	102/104	150/154	206/208
11-1-117	231/243	104/110	140/150	204/232

		11-1-118	219/231	102/104	150/150	208/236
		11-1-119	231/231	96/104	150/154	174/204
		11-1-120	231/231	96/104	150/150	204/236
		11-1-121	219/247	102/108	150/154	204/236
		11-1-122	195/227	102/108	144/154	216/228
		11-1-123	215/219	102/108	150/152	174/216
		11-1-124	219/231	96/108	150/154	208/236
		11-1-125	231/231	96/108	150/150	174/204
BB11	2	Dam 2	195/215	108/118	144/150	174/228
		Sire 1	219/231	96/102	150/154	174/236
		Sire 2	219/227	102/108	152/152	206/216
		Sire 3	235/243	100/110	138/146	196/232
		11-2-1	—	102/108	150/154	174/174
		11-2-2	195/227	108/118	144/152	216/228
		11-2-3	195/231	102/108	150/154	174/174
		11-2-4	215/247	102/108	144/154	174/228
		11-2-5	215/231	96/118	150/150	174/228
		11-2-6	195/247	102/108	150/154	174/236
		11-2-7	195/231	102/108	144/150	174/174
		11-2-8	195/247	102/118	150/154	174/174
		11-2-9	215/247	102/118	150/154	174/228
		11-2-10	195/247	102/108	144/154	174/228
		11-2-11	195/231	102/118	150/154	174/174
		11-2-12	195/231	102/118	144/150	174/236
		11-2-13	215/247	96/108	144/150	174/228
		11-2-14	195/195	96/108	144/150	174/236
		11-2-15	195/195	96/118	144/150	174/174
		11-2-16	195/231	96/118	144/154	174/174
		11-2-17	195/247	102/108	150/154	174/174
		11-2-18	195/247	102/108	150/150	174/236
		11-2-19	195/247	96/108	144/150	174/236
		11-2-20	215/235	108/110	146/150	196/228
		11-2-21	195/227	108/118	144/152	206/228
		11-2-22	195/247	96/108	144/150	228/236
		11-2-23	215/247	96/108	150/154	174/228
		11-2-24	215/247	96/118	144/150	174/236
		11-2-25	195/247	102/108	150/150	174/228
		11-2-26	195/219	108/108	144/152	216/228

11-2-27	215/219	108/108	150/154	174/206
11-2-28	195/231	102/118	150/150	174/228
11-2-29	215/227	102/108	150/154	174/216
11-2-30	215/227	108/118	144/154	174/206
11-2-31	215/227	108/118	144/152	206/228
11-2-32	215/231	96/108	144/154	174/236
11-2-33	195/247	96/118	150/150	174/228
11-2-34	195/227	102/118	150/154	216/228
11-2-35	195/247	96/108	150/150	174/236
11-2-36	195/231	102/108	144/154	174/236
11-2-37	215/227	102/108	144/154	174/206
11-2-38	215/231	96/118	144/150	174/236
11-2-39	195/231	96/118	150/150	174/228
11-2-40	195/231	102/108	150/154	174/174
11-2-41	195/227	102/108	144/154	216/228
11-2-42	215/247	102/108	144/154	228/236
11-2-43	215/243	108/110	140/144	228/232
11-2-44	195/247	96/118	150/154	174/236
11-2-45	——	——	——	——
11-2-46	215/231	102/108	144/154	174/174
11-2-47	215/247	96/118	150/154	174/174
11-2-48	195/219	108/108	150/152	174/216
11-2-49	215/219	102/118	150/154	174/216
11-2-50	227/235	96/118	150/154	174/228
11-2-51	215/247	102/108	150/154	174/236
11-2-52	215/227	102/108	150/154	174/206
11-2-53	215/227	102/118	150/152	174/206
11-2-54	215/227	102/108	150/154	206/228
11-2-55	215/247	96/118	144/154	174/174
11-2-56	215/227	108/118	144/154	174/204
11-2-57	215/247	102/108	144/150	174/236
11-2-58	195/235	108/110	146/150	228/232
11-2-59	195/227	108/118	150/152	174/216
11-2-60	195/247	102/108	150/154	174/174
11-2-61	195/247	102/108	144/154	228/236
11-2-62	195/231	102/108	144/150	174/228
11-2-63	227/235	96/118	144/154	174/174
11-2-64	195/243	110/118	144/146	174/196

11-2-65	195/231	96/108	144/150	174/228
11-2-66	195/243	108/110	144/146	174/196
11-2-67	215/227	102/118	144/154	216/228
11-2-68	195/247	102/118	144/150	174/174
11-2-69	195/231	102/118	150/150	174/236
11-2-70	215/227	102/108	144/154	174/206
11-2-71	195/231	96/108	144/150	174/236
11-2-72	215/231	102/118	144/150	174/174
11-2-73	195/235	110/118	140/150	174/196
11-2-74	215/227	108/108	150/154	174/216
11-2-75	195/243	110/118	140/144	174/196
11-2-76	215/243	108/110	144/146	174/232
11-2-77	195/247	102/118	150/160	174/174
11-2-78	215/235	100/118	146/150	174/196
11-2-79	195/231	102/108	144/154	174/236
11-2-80	195/231	102/118	144/154	228/236
11-2-81	215/247	96/118	144/154	174/228
11-2-82	195/219	108/108	144/152	174/206
11-2-83	215/231	96/108	150/150	174/236
11-2-84	215/227	102/118	144/152	174/216
11-2-85	195/231	102/108	150/154	228/236
11-2-86	195/231	102/118	150/150	174/236
11-2-87	195/227	102/118	144/152	174/207
11-2-88	195/219	108/118	144/152	174/206
11-2-89	215/235	100/108	144/146	174/232
11-2-90	215/227	102/108	150/154	174/206
11-2-91	195/231	102/108	144/150	174/228
11-2-92	215/219	102/118	150/152	174/216
11-2-93	195/231	102/108	150/150	——
11-2-94	215/247	96/108	150/154	174/236
11-2-95	195/231	102/118	144/154	228/236
11-2-96	195/243	110/118	146/150	196/228
11-2-97	215/235	100/118	140/144	174/232
11-2-98	215/231	102/118	144/150	174/228
11-2-99	195/247	96/118	144/150	174/174
11-2-100	195/231	102/108	144/154	228/236
11-2-101	215/227	108/118	144/152	206/228
11-2-102	195/247	96/118	144/150	228/236

		11-2-103	195/219	102/108	144/152	206/228
		11-2-104	215/219	102/108	144/154	206/228
		11-2-105	195/247	102/108	144/154	174/174
		11-2-106	215/235	110/118	144/146	228/232
		11-2-107	195/247	102/118	144/154	228/236
		11-2-108	195/247	96/108	144/150	174/236
		11-2-109	215/215	96/118	150/154	228/236
		11-2-110	215/243	110/118	144/146	196/228
		11-2-111	215/247	102/108	150/150	174/228
		11-2-112	215/231	96/108	144/150	174/236
		11-2-113	215/231	102/108	150/154	228/236
		11-2-114	195/219	108/108	150/152	206/228
		11-2-115	195/247	96/118	150/154	228/236
		11-2-116	195/247	102/108	144/150	174/236
		11-2-117	195/219	102/118	150/152	206/228
		11-2-118	195/231	96/108	144/154	174/174
		11-2-119	215/219	108/118	150/152	216/228
		11-2-120	215/247	96/108	144/150	174/236
		11-2-121	195/219	108/108	144/154	216/228
		11-2-122	215/247	96/118	150/154	174/228
		11-2-123	215/235	110/118	146/150	174/196
		11-2-124	215/231	96/108	150/150	174/174
		11-2-125	215/243	100/118	140/150	228/232
BB12	1	Dam 1	227/231	100/106	138/140	190/232
		Sire 1	235/243	106/114	146/158	188/214
		Sire 2	215/215	106/114	140/162	200/222
		12-1-1	231/235	106/106	140/146	190/214
		12-1-2	227/235	106/106	140/146	190/230
		12-1-3	231/243	100/106	140/158	—
		12-1-4	231/243	100/114	140/158	214/232
		12-1-5	227/235	100/114	140/146	190/214
		12-1-6	231/235	100/114	140/158	190/230
		12-1-7	231/247	106/106	140/140	190/200
		12-1-8	227/243	106/106	140/146	—
		12-1-9	231/235	100/106	140/146	190/214
		12-1-10	231/235	106/106	140/146	214/232
		12-1-11	227/243	100/114	140/146	—
		12-1-12	231/235	100/106	140/158	—



12-1-13	231/243	100/114	140/158	214/232
12-1-14	231/243	106/106	140/158	214/232
12-1-15	231/235	106/114	140/158	190/230
12-1-16	227/235	106/106	140/158	214/232
12-1-17	215/227	100/114	140/162	190/200
12-1-18	215/227	106/106	140/162	200/200
12-1-19	227/247	100/114	140/162	190/222
12-1-20	227/235	100/106	140/158	214/232
12-1-21	231/247	100/106	140/140	200/232
12-1-22	227/235	100/114	140/158	190/230
12-1-23	227/235	100/114	140/146	190/190
12-1-24	227/235	100/114	140/146	190/230
12-1-25	231/235	100/106	140/158	——
12-1-26	231/243	106/106	140/146	190/214
12-1-27	231/235	106/114	140/146	214/232
12-1-28	231/243	106/106	140/158	190/230
12-1-29	231/243	106/114	140/146	190/230
12-1-30	231/243	100/114	140/146	190/214
12-1-31	231/235	100/114	140/146	190/190
12-1-32	227/243	106/114	140/158	214/232
12-1-33	231/243	106/106	140/146	214/232
12-1-34	——	——	——	——
12-1-35	231/243	106/114	140/158	230/232
12-1-36	231/235	106/114	140/146	230/232
12-1-37	231/243	100/106	140/146	——
12-1-38	215/227	100/106	140/140	190/200
12-1-39	227/235	100/114	140/158	190/230
12-1-40	231/235	106/106	140/146	190/232
12-1-41	231/243	106/106	140/146	190/190
12-1-42	227/235	100/114	140/158	214/232
12-1-43	227/235	106/114	140/146	214/232
12-1-44	215/227	100/114	140/140	200/232
12-1-45	231/243	106/106	140/146	190/214
12-1-46	227/235	100/106	140/146	190/230
12-1-47	231/243	106/114	140/140	214/234
12-1-48	227/247	106/114	140/140	190/200
12-1-49	231/235	106/114	140/146	190/230
12-1-50	227/235	100/106	140/140	190/214

12-1-51	227/243	100/114	140/146	190/230
12-1-52	231/243	100/114	140/158	230/232
12-1-53	227/235	100/114	140/158	190/230
12-1-54	227/247	106/106	140/140	190/222
12-1-55	227/235	106/114	140/146	230/232
12-1-56	227/243	106/106	140/158	214/232
12-1-57	227/235	100/106	140/146	230/232
12-1-58	227/235	100/106	140/146	190/230
12-1-59	227/247	100/114	140/162	222/232
12-1-60	227/235	106/106	140/146	190/214
12-1-61	227/235	106/114	140/146	190/214
12-1-62	227/243	106/114	140/158	214/232
12-1-63	227/235	100/114	140/158	230/232
12-1-64	231/235	106/114	140/158	230/232
12-1-65	215/231	100/114	140/162	190/222
12-1-66	231/243	106/114	140/146	230/232
12-1-67	231/243	100/106	140/146	190/214
12-1-68	231/247	106/106	140/158	230/232
12-1-69	231/243	106/114	140/146	214/232
12-1-70	227/235	106/114	140/146	190/230
12-1-71	227/235	106/106	140/158	190/230
12-1-72	231/243	100/106	140/158	190/230
12-1-73	231/235	100/106	140/146	190/230
12-1-74	231/235	100/106	140/158	190/190
12-1-75	227/243	106/114	140/158	214/230
12-1-76	227/235	106/114	140/158	190/214
12-1-77	227/243	100/114	140/146	230/232
12-1-78	——	——	——	——
12-1-79	231/235	100/106	140/158	190/190
12-1-80	231/243	100/114	140/146	230/232
12-1-81	215/231	100/114	140/140	222/232
12-1-82	227/243	106/114	140/146	190/230
12-1-83	231/235	100/106	140/158	190/230
12-1-84	215/231	106/106	140/140	222/232
12-1-85	227/243	100/114	140/158	190/214
12-1-86	231/235	100/106	140/146	230/232
12-1-87	231/235	106/114	140/158	190/230
12-1-88	231/235	100/114	140/146	190/214

		12-1-89	227/243	106/114	140/158	190/230
		12-1-90	231/243	100/114	140/158	214/232
		12-1-91	227/235	100/114	140/158	214/232
		12-1-92	227/235	104/106	140/158	190/214
		12-1-93	227/235	100/114	140/158	230/232
		12-1-94	231/243	106/106	140/146	214/232
		12-1-95	231/247	100/106	140/162	200/232
		12-1-96	231/243	100/106	140/158	190/230
		12-1-97	227/235	106/114	140/158	230/232
		12-1-98	231/247	100/114	140/146	190/214
		12-1-99	227/235	106/106	140/158	214/232
		12-1-100	231/235	106/106	140/158	190/214
		12-1-101	227/243	106/106	140/158	190/230
		12-1-102	231/247	106/114	140/162	200/232
		12-1-103	227/235	106/114	140/146	230/232
		12-1-104	231/243	106/114	140/146	190/230
		12-1-105	227/243	100/106	140/146	190/230
		12-1-106	231/235	100/114	140/158	190/214
		12-1-107	227/235	100/114	140/158	212/232
		12-1-108	231/235	106/106	140/146	230/232
		12-1-109	231/243	100/106	140/158	230/232
		12-1-110	227/235	100/114	140/146	190/214
		12-1-111	227/243	100/106	140/158	214/232
		12-1-112	231/235	106/114	140/158	190/230
		12-1-113	215/227	100/106	140/162	190/200
		12-1-114	231/243	106/106	140/146	190/230
		12-1-115	231/235	100/114	140/158	190/214
		12-1-116	231/243	100/106	140/158	214/232
		12-1-117	227/247	100/106	140/162	190/200
		12-1-118	227/235	106/114	140/146	190/230
		12-1-119	215/231	100/114	140/162	200/232
		12-1-120	227/243	100/114	140/146	190/214
		12-1-121	227/243	100/106	140/146	214/232
		12-1-122	227/243	100/106	140/146	230/232
		12-1-123	227/243	106/106	140/158	190/232
		12-1-124	231/243	100/106	140/158	214/232
		12-1-125	231/243	100/114	140/158	190/224
VB3-1	1	Dam 3	247/247	100/102	140/148	194/208

Sire 1	227/231	94/94	146/158	200/224
Sire 2	231/239	100/106	142/144	210/228
31-1-1	227/247	94/102	148/158	208/224
31-1-2	231/247	94/100	146/148	208/224
31-1-3	227/247	94/102	140/158	194/200
31-1-4	231/247	94/102	140/146	194/200
31-1-5	227/247	94/102	140/158	208/224
31-1-6	227/247	94/102	146/148	208/224
31-1-7	231/247	94/100	140/158	208/224
31-1-8	231/247	94/100	148/158	194/224
31-1-9	231/247	100/106	140/144	208/210
31-1-10	227/247	94/100	146/148	194/200
31-1-11	227/247	94/100	140/158	200/208
31-1-12	227/247	94/100	148/158	194/200
31-1-13	231/247	94/102	140/158	194/200
31-1-14	227/247	94/102	146/148	194/224
31-1-15	—	—	—	—
31-1-16	227/247	94/100	140/158	208/224
31-1-17	231/247	94/100	146/148	200/208
31-1-18	231/247	94/100	140/158	200/208
31-1-19	231/247	94/100	140/158	194/224
31-1-20	227/247	94/100	146/148	200/208
31-1-21	231/247	94/100	146/148	194/200
31-1-22	231/247	94/102	148/158	200/208
31-1-23	231/231	94/100	140/158	200/208
31-1-24	—	—	—	—
31-1-25	231/247	94/100	148/158	194/200
31-1-26	227/247	94/100	140/146	208/224
31-1-27	231/247	94/102	148/158	194/200
31-1-28	—	—	—	—
31-1-29	231/247	94/102	140/158	194/200
31-1-30	231/247	100/100	144/148	208/228
31-1-31	231/247	94/102	148/158	200/208
31-1-32	227/247	94/100	140/146	200/208
31-1-33	231/247	94/102	140/158	200/208
31-1-34	—	—	—	—
31-1-35	231/247	94/100	140/158	208/224
31-1-36	231/247	94/102	148/158	200/208

31-1-37	227/247	94/102	140/146	200/208
31-1-38	227/247	94/100	146/148	194/224
31-1-39	227/247	94/102	140/146	208/224
31-1-40	227/247	94/100	146/148	200/208
31-1-41	231/247	94/100	146/148	200/208
31-1-42	231/247	94/102	140/158	200/208
31-1-43	227/247	94/102	140/158	208/224
31-1-44	——	——	——	——
31-1-45	227/247	94/102	148/158	200/208
31-1-46	231/247	94/102	140/146	208/224
31-1-47	231/247	94/102	148/158	200/208
31-1-48	227/247	94/102	146/148	208/224
31-1-49	231/247	94/102	148/158	194/200
31-1-50	227/247	94/100	148/158	208/224
31-1-51	227/247	94/100	146/148	194/200
31-1-52	227/247	94/102	140/158	208/224
31-1-53	231/247	94/100	140/158	194/224
31-1-54	239/247	100/102	140/144	208/228
31-1-55	231/247	100/106	140/144	208/228
31-1-56	227/247	94/100	140/146	200/208
31-1-57	——	94/102	140/146	194/224
31-1-58	231/247	94/100	146/148	200/208
31-1-59	——	——	——	——
31-1-60	231/247	94/100	140/146	200/208
31-1-61	231/247	94/100	146/148	194/224
31-1-62	231/247	94/100	140/158	194/200
31-1-63	227/247	94/102	140/146	194/224
31-1-64	231/247	94/102	140/158	194/224
31-1-65	227/247	94/102	140/146	208/224
31-1-66	227/247	94/100	140/146	194/224
31-1-67	231/247	94/102	148/158	200/208
31-1-68	231/247	94/102	140/158	200/208
31-1-69	227/247	94/100	146/148	200/208
31-1-70	231/247	102/106	144/148	194/210
31-1-71	227/247	94/100	148/158	194/224
31-1-72	227/247	94/102	140/146	208/224
31-1-73	231/247	94/102	146/148	200/208
31-1-74	——	——	——	——

31-1-75	231/247	94/100	148/158	194/200
31-1-76	231/247	100/102	140/144	194/228
31-1-77	227/247	94/102	140/146	194/200
31-1-78	227/247	94/100	146/148	208/224
31-1-79	231/247	94/102	146/148	194/200
31-1-80	227/247	94/100	146/148	208/224
31-1-81	231/247	100/102	144/148	194/228
31-1-82	——	——	——	——
31-1-83	231/247	94/102	140/158	194/224
31-1-84	231/247	94/102	140/158	194/224
31-1-85	231/247	94/102	148/158	194/224
31-1-86	227/247	94/100	148/158	194/224
31-1-87	227/247	94/102	146/148	188/190
31-1-88	——	——	——	——
31-1-89	——	——	——	——
31-1-90	——	——	——	——
31-1-91	231/247	94/102	140/146	208/224
31-1-92	227/247	94/102	146/148	208/224
31-1-93	231/247	94/102	146/148	194/224
31-1-94	227/247	94/102	148/158	200/208
31-1-95	231/247	102/106	144/148	194/210
31-1-96	227/247	94/100	140/146	194/224
31-1-97	231/247	94/100	140/146	194/200
31-1-98	231/247	94/100	146/148	194/224
31-1-99	231/247	94/102	140/158	194/224
31-1-100	239/247	100/100	140/144	194/210
31-1-101	227/247	94/102	148/158	194/224
31-1-102	227/247	94/100	148/158	——
31-1-103	231/247	94/100	140/158	194/200
31-1-104	227/247	94/100	146/148	200/208
31-1-105	231/247	94/102	148/158	208/224
31-1-106	——	——	——	——
31-1-107	231/247	94/100	140/146	200/208
31-1-108	227/247	94/100	148/158	200/208
31-1-109	231/247	94/100	144/144	——
31-1-110	231/247	94/100	140/146	194/224
31-1-111	227/247	94/102	148/158	200/208
31-1-112	231/247	94/100	146/148	194/224

		31-1-113	231/247	94/102	148/158	194/224
		31-1-114	239/247	100/100	140/144	194/210
		31-1-115	227/247	94/100	140/146	200/208
		31-1-116	231/247	94/100	140/146	194/200
		31-1-117	231/247	94/102	148/158	194/200
		31-1-118	227/247	94/100	148/158	194/200
		31-1-119	—	—	—	—
		31-1-120	239/255	96/104	148/158	208/224
		31-1-121	231/247	94/100	146/148	194/224
		31-1-122	231/247	94/102	146/148	194/224
		31-1-123	231/247	94/100	140/158	—
		31-1-124	231/247	94/100	140/158	—
		31-1-125	227/247	94/102	140/146	—
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VB3-3	1	Dam 3	219/219	106/106	146/148	220/228
		Sire 2	215/239	104/106	138/138	206/212
		33-1-1	219/239	104/106	140/148	212/220
		33-1-2	215/219	104/106	140/148	—
		33-1-3	219/239	106/106	138/148	206/228
		33-1-4	219/239	104/106	138/148	212/220
		33-1-5	—	—	—	—
		33-1-6	215/219	104/106	138/148	212/220
		33-1-7	219/239	106/106	140/148	212/220
		33-1-8	215/219	104/106	138/148	206/220
		33-1-9	219/239	104/106	138/148	206/228
		33-1-10	215/219	104/106	138/148	206/220
		33-1-11	215/219	106/106	138/148	212/228
		33-1-12	219/239	106/106	140/148	212/220
		33-1-13	215/219	106/106	138/148	206/220
		33-1-14	215/219	106/106	140/148	206/228
		33-1-15	219/239	106/106	140/148	206/228
		33-1-16	219/239	106/106	138/148	212/228
		33-1-17	215/219	106/106	138/148	212/228
		33-1-18	219/239	104/106	138/148	212/228
		33-1-19	219/239	104/106	140/148	212/228
		33-1-20	219/239	104/106	140/148	206/220
		33-1-21	219/239	106/106	138/148	206/228
		33-1-22	219/239	104/106	140/148	212/220
		33-1-23	219/239	104/106	140/148	206/220

33-1-24	215/219	104/106	138/148	206/228
33-1-25	219/239	106/106	138/148	206/220
33-1-26	215/219	104/106	138/148	212/220
33-1-27	215/219	106/106	140/148	212/228
33-1-28	215/219	104/106	140/148	212/220
33-1-29	215/219	104/106	138/148	206/228
33-1-30	215/219	106/106	138/148	212/228
33-1-31	219/239	104/106	138/148	212/228
33-1-32	215/219	106/106	140/148	212/220
33-1-33	219/239	106/106	140/148	212/228
33-1-34	215/219	104/106	140/148	212/220
33-1-35	219/239	104/106	140/148	206/220
33-1-36	219/239	104/106	140/148	206/220
33-1-37	215/219	106/106	140/148	212/228
33-1-38	219/239	104/106	140/148	212/228
33-1-39	215/219	106/106	140/148	212/220
33-1-40	219/239	104/106	138/148	212/228
33-1-41	215/219	104/106	138/148	212/220
33-1-42	215/219	106/106	138/148	206/228
33-1-43	215/219	106/106	138/148	212/220
33-1-44	215/219	104/106	140/148	206/228
33-1-45	215/219	106/106	140/148	212/228
33-1-46	215/219	106/106	138/148	206/228
33-1-47	215/219	104/106	140/148	206/220
33-1-48	215/219	104/106	138/148	206/220
33-1-49	219/239	104/106	138/148	212/220
33-1-50	219/239	106/106	138/148	212/220
33-1-51	219/239	106/106	140/148	212/220
33-1-52	219/239	104/106	138/148	212/228
33-1-53	215/219	104/106	140/148	206/220
33-1-54	215/219	104/106	140/148	212/220
33-1-55	215/219	104/106	138/148	212/220
33-1-56	215/219	104/106	140/148	206/228
33-1-57	219/239	104/106	140/148	206/220
33-1-58	219/239	106/106	138/148	212/220
33-1-59	215/219	104/106	138/148	212/220
33-1-60	219/239	104/106	138/148	212/220
33-1-61	219/239	104/106	138/148	212/228



33-1-62	219/239	104/106	138/148	212/228
33-1-63	219/239	104/106	138/148	212/228
33-1-64	219/239	104/106	140/148	206/220
33-1-65	215/219	106/106	138/148	206/228
33-1-66	215/219	104/106	138/148	206/220
33-1-67	215/219	104/106	140/148	206/228
33-1-68	219/239	106/106	138/148	206/228
33-1-69	215/219	106/106	140/148	206/220
33-1-70	219/239	106/106	138/148	206/220
33-1-71	215/219	104/106	140/148	212/220
33-1-72	219/239	104/106	138/148	212/220
33-1-73	215/219	104/106	138/148	212/220
33-1-74	215/219	104/106	138/148	212/220
33-1-75	215/219	106/106	140/148	206/220
33-1-76	215/219	106/106	140/148	——
33-1-77	215/219	106/106	140/148	206/228
33-1-78	215/219	104/106	138/148	206/228
33-1-79	215/219	106/106	140/148	206/226
33-1-80	219/239	106/106	138/148	212/228
33-1-81	219/239	106/106	138/148	206/206
33-1-82	219/239	104/104	140/148	206/220
33-1-83	219/239	106/106	140/148	206/228
33-1-84	215/219	104/106	138/148	206/228
33-1-85	215/219	104/106	140/148	206/220
33-1-86	215/219	104/106	140/148	212/220
33-1-87	215/219	106/106	140/148	212/220
33-1-88	219/239	104/106	140/148	206/220
33-1-89	219/239	106/106	140/148	212/220
33-1-90	215/219	104/106	138/148	212/220
33-1-91	215/219	104/106	138/148	212/220
33-1-92	215/219	106/106	140/148	212/228
33-1-93	219/239	104/106	140/148	212/228
33-1-94	215/219	106/106	140/148	206/228
33-1-95	215/219	106/106	140/148	206/228
33-1-96	215/219	104/106	140/148	206/220
33-1-97	219/239	106/106	138/148	212/228
33-1-98	219/239	104/106	138/148	206/220
33-1-99	219/239	104/106	138/148	212/228

		33-1-100	215/219	106/106	138/148	212/220
		33-1-101	215/219	106/106	138/148	212/228
		33-1-102	219/239	104/106	138/148	206/222
		33-1-103	215/219	104/106	138/148	206/228
		33-1-104	215/219	104/106	140/148	206/220
		33-1-105	219/239	106/106	138/148	206/220
		33-1-106	215/219	106/106	138/148	212/220
		33-1-107	215/219	106/106	140/148	212/220
		33-1-108	219/239	104/106	140/148	206/228
		33-1-109	215/219	104/106	140/148	206/206
		33-1-110	219/239	104/106	138/148	206/220
		33-1-111	215/219	104/106	138/148	206/228
		33-1-112	219/239	104/106	140/148	206/228
		33-1-113	219/239	104/106	140/148	206/228
		33-1-114	219/239	106/106	140/148	212/228
		33-1-115	215/219	104/106	138/148	206/228
		33-1-116	219/239	106/106	138/148	206/220
		33-1-117	215/219	106/106	138/148	212/228
		33-1-118	219/239	104/106	138/148	206/228
		33-1-119	219/239	106/106	138/148	212/220
		33-1-120	219/239	106/106	140/148	212/220
		33-1-121	215/219	104/106	138/148	212/220
		33-1-122	219/239	106/106	138/148	212/228
		33-1-123	215/219	104/106	140/148	212/228
		33-1-124	215/219	106/106	138/148	206/228
		33-1-125	215/219	106/106	138/148	212/228
VB4-1	1	Dam 2	199/223	106/106	140/148	188/198
		Dam 3	231/239	94/122	146/146	194/212
		Sire 1	215/267	98/106	140/144	190/210
		Sire 2	223/223	98/110	138/144	188/194
		41-1-1	223/223	106/110	138/148	188/198
		41-1-2	219/223	98/108	140/144	194/242
		41-1-3	219/223	98/108	138/140	188/196
		41-1-4	223/227	102/110	140/144	188/196
		41-1-5	223/227	98/108	138/150	188/196
		41-1-6	219/223	98/102	138/150	194/196
		41-1-7	199/223	106/110	138/140	188/188
		41-1-8	219/223	108/110	138/140	194/242

41-1-9	219/223	98/108	138/150	194/242
41-1-10	223/227	102/110	138/150	188/196
41-1-11	219/223	98/108	138/150	188/242
41-1-12	223/223	106/110	138/140	188/198
41-1-13	223/227	98/102	140/144	194/196
41-1-14	223/227	98/108	144/150	194/242
41-1-15	223/227	98/102	140/144	194/196
41-1-16	223/227	108/110	140/144	194/242
41-1-17	223/227	98/108	138/140	188/242
41-1-18	223/227	102/110	140/144	188/196
41-1-19	223/227	108/110	144/150	194/196
41-1-20	223/227	102/110	144/150	188/196
41-1-21	219/223	98/102	138/140	188/242
41-1-22	219/223	98/108	138/150	194/242
41-1-23	219/223	108/110	144/150	194/196
41-1-24	219/223	98/102	140/144	194/196
41-1-25	219/223	102/110	144/150	194/242
41-1-26	223/227	98/108	138/150	194/242
41-1-27	219/223	108/110	144/150	194/196
41-1-28	219/223	108/110	144/150	188/242
41-1-29	223/227	98/108	144/150	194/196
41-1-30	223/227	98/102	138/150	188/196
41-1-31	223/227	108/110	140/144	194/196
41-1-32	223/227	98/102	138/150	188/242
41-1-33	223/227	98/108	138/140	188/196
41-1-34	199/223	106/110	144/148	188/198
41-1-35	219/223	102/110	138/140	194/242
41-1-36	223/227	108/110	144/150	188/196
41-1-37	223/227	98/102	140/144	194/242
41-1-38	223/227	102/110	140/144	188/196
41-1-39	199/267	106/106	140/144	190/198
41-1-40	223/227	108/110	144/140	194/242
41-1-41	219/223	108/110	138/140	188/196
41-1-42	223/227	98/102	138/140	194/196
41-1-43	219/223	98/102	138/150	194/242
41-1-44	219/223	108/110	140/144	194/196
41-1-45	219/223	102/110	138/140	188/242
41-1-46	223/227	102/110	144/150	188/196

41-1-47	223/227	98/102	138/150	188/242
41-1-48	199/223	106/110	144/148	194/198
41-1-49	223/227	102/110	138/150	188/196
41-1-50	223/227	108/110	138/150	194/242
41-1-51	223/227	98/102	138/140	188/242
41-1-52	219/223	108/110	138/140	188/242
41-1-53	223/227	102/110	138/140	194/196
41-1-54	215/223	106/106	144/148	198/210
41-1-55	219/223	98/102	140/144	188/196
41-1-56	223/227	102/110	140/144	188/196
41-1-57	219/223	102/110	144/150	194/242
41-1-58	199/267	106/106	140/140	188/190
41-1-59	223/227	98/102	138/150	188/242
41-1-60	219/223	108/110	140/144	188/196
41-1-61	223/227	98/108	140/144	194/196
41-1-62	219/223	108/110	138/140	188/242
41-1-63	219/223	98/102	144/150	188/196
41-1-64	219/223	102/110	140/144	194/242
41-1-65	223/227	108/110	140/144	194/196
41-1-66	223/227	102/110	144/150	194/242
41-1-67	223/267	106/106	144/148	188/190
41-1-68	219/223	98/102	144/150	194/242
41-1-69	219/223	98/108	138/140	188/242
41-1-70	219/223	98/102	138/140	194/242
41-1-71	223/227	98/102	140/144	188/196
41-1-72	223/227	102/110	138/150	188/242
41-1-73	223/227	108/110	144/150	188/242
41-1-74	223/223	106/110	138/148	188/198
41-1-75	223/227	108/110	138/140	188/242
41-1-76	219/223	98/108	144/150	188/242
41-1-77	199/223	106/110	144/148	188/194
41-1-78	223/227	102/110	138/150	194/242
41-1-79	223/227	98/102	144/150	188/196
41-1-80	219/223	102/110	138/140	188/196
41-1-81	219/223	108/110	144/150	188/242
41-1-82	223/227	102/110	138/140	188/242
41-1-83	219/223	98/108	140/144	188/242
41-1-84	199/223	98/106	138/148	194/198

41-1-85	219/223	102/110	138/140	188/242
41-1-86	219/223	108/110	138/140	194/196
41-1-87	219/223	98/108	140/144	194/196
41-1-88	219/223	98/102	140/144	188/196
41-1-89	223/227	98/108	144/150	188/196
41-1-90	223/227	108/110	138/140	188/196
41-1-91	223/227	108/110	144/150	188/242
41-1-92	223/227	102/110	144/150	188/196
41-1-93	219/223	108/110	138/150	188/196
41-1-94	219/223	108/110	144/150	194/196
41-1-95	223/227	102/110	140/144	194/196
41-1-96	219/223	102/110	140/144	194/196
41-1-97	219/223	98/108	138/140	194/196
41-1-98	219/223	98/102	144/150	194/196
41-1-99	219/223	98/102	144/150	188/196
41-1-100	223/223	98/102	138/140	194/242
41-1-101	219/223	108/110	144/150	194/196
41-1-102	219/223	98/108	144/150	188/242
41-1-103	223/227	98/108	138/150	188/196
41-1-104	223/227	98/102	138/150	188/242
41-1-105	223/227	98/108	144/150	188/242
41-1-106	199/223	98/106	138/140	194/198
41-1-107	223/223	106/110	140/144	194/198
41-1-108	219/223	108/110	144/150	188/196
41-1-109	219/223	108/110	144/150	188/242
41-1-110	219/223	98/108	138/150	188/196
41-1-111	223/223	98/106	140/144	188/194
41-1-112	219/223	98/102	144/150	194/242
41-1-113	223/227	102/110	144/150	194/196
41-1-114	219/223	98/108	144/150	188/196
41-1-115	219/223	108/110	140/144	194/242
41-1-116	223/227	98/102	144/150	194/242
41-1-117	223/227	108/110	138/140	194/196
41-1-118	219/223	98/108	144/150	194/196
41-1-119	223/227	102/110	138/150	188/196
41-1-120	199/223	98/106	144/148	194/198
41-1-121	219/223	98/102	140/144	194/242
41-1-122	223/227	102/110	140/144	194/242

41-1-123	219/223	98/108	140/144	188/196
41-1-124	219/223	102/110	144/150	188/196
41-1-125	223/227	98/102	144/150	194/242

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## APPENDIX 6

Number of families and number of progeny per mating pair (dam and sire) used in experiments to estimate heritability of juvenile growth rate.

<u>Brood Tank</u>	<u>Family</u>	<u>Dam (Tag ID)</u>	<u>Sire (Tag ID)</u>	<u>Number of progeny</u>
BB2	1	Dam2 (94)	Sire2 (148)	31
	2	Dam4 (144)	Sire2 (148)	35
BB5	1	Dam1 (78)	Sire1 (3)	2
	2	Dam1 (78)	Sire2 (149)	2
BB7	1	Dam1 (52)	Sire1 (138)	3
	2	Dam1 (52)	Sire2 (139)	21
	3	Dam2 (88)	Sire1 (138)	39
	4	Dam2 (88)	Sire2 (139)	1
BB8	1	Dam1 (76)	Sire2 (146)	2
BB12	1	Dam1 (80)	Sire2 (143)	32
	1	Dam1 (77)	Sire1 (127)	13
	2	Dam1 (77)	Sire2 (132)	4
VB3-1	3	Dam2 (79)	Sire1 (127)	34
	4	Dam2 (79)	Sire2 (132)	4
	5	Dam3 (95)	Sire1 (127)	5
VB3-3	1	Dam3 (90)	Sire2 (134)	38
	1	Dam1 (51)	Sire1 (53)	2
VB4-1	2	Dam2 (57)	Sire1 (53)	24
	3	Dam3 (75)	Sire1 (53)	8
Totals	19	14 Dams	10 Sires	300

## APPENDIX 7

Weight (in grams) and length (in millimeters) of experimental progeny, separated by replicate tank (1 - 3), at each of three measurement periods (148, 189, and 208 days post-spawning) used to estimate heritability of juvenile growth rates. Progeny were identified by PIT tag number (Tag ID). Also given are genotypes (allele sizes) for each individual at each of four microsatellites (*Soc* 19, *Soc* 85, *Soc* 402, and *Soc* 428).

<u>Tank 1</u>	<u>Day 148</u>	<u>Day 148</u>	<u>Day 189</u>	<u>Day 189</u>	<u>Day 208</u>	<u>Day 208</u>				
<u>Tag ID</u>	<u>W (g)</u>	<u>L (mm)</u>	<u>W (g)</u>	<u>L (mm)</u>	<u>W (g)</u>	<u>L (mm)</u>	<u>Soc 19</u>	<u>Soc 85</u>	<u>Soc 402</u>	<u>Soc 428</u>
010a	20.57	123.00	48.88	162.00	80.60	185.00	215/219	102/104	140/146	184/200
0244	18.17	120.00	26.94	141.00	36.00	151.00	227/227	100/120	146/152	206/206
0313	—	—	40.20	159.00	58.40	173.00	215/231	100/106	140/140	190/200
035e	—	—	44.50	158.00	74.70	176.00	231/255	102/106	140/146	200/200
0360	21.32	130.00	50.53	172.00	75.80	186.00	215/231	102/106	140/148	184/200
0655	—	—	25.60	130.00	32.90	138.00	223/227	94/108	138/158	194/224
093a	23.36	127.00	47.42	164.00	62.00	178.00	231/247	106/114	140/140	190/200
0c18	16.61	117.00	26.48	140.00	32.20	145.00	223/227	96/100	140/152	192/206
0c53	22.33	130.00	50.26	173.00	75.80	189.00	215/227	96/102	140/152	184/206
0d7c	23.45	132.00	33.34	152.00	48.00	162.00	227/231	96/100	140/152	192/206
0e31	20.23	125.00	35.31	152.00	42.60	162.00	227/231	118/120	140/146	188/192
0f01	—	—	47.90	160.00	73.80	174.00	207/231	94/106	144/158	190/224
0f4c	23.08	130.00	48.69	168.00	75.10	184.00	219/227	104/108	150/154	204/216
0f58	24.79	131.00	52.10	171.00	82.40	187.00	231/247	100/114	140/162	190/200
0f5a	20.64	127.00	30.80	149.00	39.50	158.00	223/227	96/118	146/146	192/206
1251	22.97	130.00	41.44	157.00	54.10	164.00	231/247	106/106	140/162	190/200
1275	23.29	135.00	39.16	164.00	60.80	180.00	223/227	96/118	140/152	188/206
131a	16.29	117.00	39.10	158.00	58.80	174.00	231/247	106/114	140/140	190/222



142c	26.48	136.00	55.70	178.00	74.70	196.00	231/247	106/106	140/140	222/232
1454	21.06	125.00	40.30	157.00	51.80	165.00	231/247	100/114	140/140	190/222
1530	25.40	137.00	56.30	175.00	90.50	197.00	215/227	100/106	140/140	222/232
1954	—	—	27.58	141.00	38.70	151.00	227/227	118/120	146/146	192/206
1c7a	20.56	123.00	38.40	155.00	65.00	170.00	207/231	94/102	144/158	194/200
202c	14.83	110.00	28.00	139.00	44.90	154.00	227/231	94/102	146/150	190/200
2041	17.76	119.00	39.40	145.00	—	—	215/227	94/108	158/160	194/224
2104	—	—	39.80	154.00	64.00	172.00	231/247	94/100	148/158	208/224
2631	—	—	38.50	154.00	59.20	174.00	227/247	100/106	140/140	222/232
2668	21.47	125.00	47.90	160.00	79.00	180.00	215/235	80/102	150/152	224/232
274c	19.95	125.00	33.40	148.00	49.90	159.00	207/231	94/102	146/150	190/224
2755	—	—	33.10	143.00	51.20	155.00	223/235	102/106	148/150	224/232
2830	17.83	121.00	45.10	165.00	75.10	184.00	215/223	100/106	148/150	188/224
2a4f	19.97	124.00	44.90	162.00	70.00	180.00	215/235	80/102	150/152	188/232
2b4c	20.91	127.00	43.20	164.00	62.90	180.00	235/235	100/106	148/150	188/232
2b74	15.29	113.00	30.60	142.00	37.50	150.00	215/223	102/106	148/150	188/232
2c14	17.75	123.00	40.10	157.00	61.10	170.00	215/223	80/102	150/152	188/220
2c4d	17.79	118.00	35.50	149.00	51.00	161.00	215/235	80/100	150/152	188/232
2d05	16.48	116.00	35.20	148.00	46.30	160.00	215/235	80/102	148/150	224/232
321d	17.07	116.00	19.50	124.00	—	—	215/235	100/106	150/152	188/224
372b	15.35	112.00	29.10	140.00	41.90	154.00	215/235	80/102	148/150	188/224
394e	—	—	25.00	135.00	34.90	142.00	231/247	94/102	148/158	200/208
3c11	13.52	108.00	31.80	144.00	49.90	160.00	227/227	94/102	150/158	190/200
4336	23.57	130.00	36.40	155.00	49.90	168.00	215/227	94/100	146/148	190/194
4358	—	—	52.40	174.00	80.00	191.00	223/267	98/106	146/146	190/198
436a	18.22	120.00	21.30	130.00	30.00	138.00	227/231	96/118	140/152	188/206
4418	20.70	125.00	43.30	162.00	74.40	184.00	227/235	100/110	140/150	188/206

443f	15.42	111.00	24.40	133.00	37.20	147.00	215/223	102/110	140/150	188/206
4447	19.17	123.00	37.30	155.00	58.60	175.00	227/235	102/110	—	206/232
4713	20.56	123.00	43.30	160.00	70.90	179.00	215/231	102/104	146/148	188/188
474c	17.90	120.00	28.70	142.00	40.20	152.00	215/219	102/104	140/146	184/200
4d05	21.60	124.00	36.40	151.00	52.90	162.00	207/227	94/106	146/150	190/224
4d57	—	—	24.00	135.00	34.40	149.00	227/235	100/100	140/150	192/232
4e3a	18.99	123.00	32.20	150.00	42.50	161.00	215/231	94/100	158/160	194/200
4e5d	29.93	145.00	52.40	175.00	79.60	191.00	223/231	94/100	138/146	194/224
4f77	—	—	45.80	164.00	65.90	173.00	215/231	106/106	140/162	200/232
5104	—	—	46.60	163.00	53.30	169.00	227/247	100/114	140/140	190/222
511c	19.14	123.00	28.90	143.00	42.30	154.00	215/231	94/100	146/160	194/224
5147	32.06	144.00	57.80	178.00	83.00	195.00	215/227	94/108	138/158	194/200
5261	20.71	125.00	40.00	156.00	62.10	164.00	227/231	94/106	146/150	194/224
5437	19.06	123.00	34.30	150.00	54.10	164.00	223/227	94/108	138/146	194/200
583f	—	—	58.30	171.00	87.40	184.00	227/231	94/106	146/150	190/200
5b30	—	—	52.30	163.00	80.40	184.00	215/219	104/106	138/148	206/206
5c67	14.97	110.00	25.70	136.00	35.70	146.00	223/231	94/100	146/160	194/224
5d18	31.09	142.00	58.70	179.00	91.40	200.00	215/231	94/108	138/146	194/200
5d1c	27.91	136.00	60.60	178.00	96.40	200.00	227/231	94/102	150/158	194/224
5d1f	23.97	132.00	39.80	160.00	57.70	174.00	215/231	100/100	138/144	194/228
6009	13.90	108.00	34.20	147.00	51.80	162.00	219/239	104/106	140/148	212/228
6172	29.26	140.00	68.90	180.00	113.10	203.00	219/239	106/106	138/148	206/220
6309	19.22	123.00	52.30	172.00	87.70	192.00	215/219	104/106	138/148	212/228
6914	—	—	36.40	152.00	49.70	162.00	227/247	100/114	140/140	200/232
6357	19.57	122.00	37.10	151.00	57.10	170.00	219/231	102/104	150/154	174/204
636a	17.60	117.00	36.40	147.00	49.10	160.00	215/219	104/106	138/148	192/206
6866	27.25	131.00	65.50	173.00	91.30	192.00	219/239	106/106	140/148	206/228

693a	—	—	34.00	153.00	49.00	164.00	215/219	102/106	140/146	200/200
6978	27.37	135.00	66.60	180.00	88.30	192.00	219/239	104/106	140/148	206/220
697c	31.43	144.00	68.80	187.00	111.10	205.00	227/235	100/110	140/150	188/206
6a3e	15.70	110.00	33.60	140.00	45.60	160.00	215/219	104/106	138/148	206/218
6b10	25.41	135.00	44.30	165.00	72.00	184.00	231/255	102/104	140/140	184/200
6c31	14.21	113.00	22.30	130.00	32.40	139.00	223/235	100/110	150/164	192/232
6c59	14.91	110.00	28.10	140.00	42.40	154.00	231/231	96/104	150/150	174/204
6e5a	22.99	131.00	38.10	156.00	63.40	174.00	223/235	100/102	140/150	206/232
6f56	19.92	121.00	38.60	150.00	61.30	161.00	215/235	80/100	148/150	188/188
7055	—	—	33.90	145.00	56.70	165.00	219/239	106/106	140/148	190/212
706a	21.96	130.00	43.70	165.00	62.90	180.00	215/223	98/106	140/144	198/210
715d	23.57	130.00	49.40	167.00	72.90	185.00	199/215	98/106	140/144	190/198
737b	24.39	129.00	46.40	160.00	74.10	175.00	227/235	100/100	150/164	188/206
745d	21.58	125.00	36.20	155.00	56.40	172.00	215/223	100/102	150/164	206/232
7645	31.13	143.00	52.00	170.00	70.80	183.00	223/235	102/110	140/150	188/192
7731	12.96	110.00	26.40	136.00	40.80	151.00	215/223	102/110	140/150	188/192
773e	15.19	115.00	27.30	141.00	45.40	161.00	215/223	100/102	140/150	192/232
7749	14.41	112.00	23.80	135.00	38.90	149.00	227/235	100/100	140/150	188/192
775a	23.59	130.00	34.90	150.00	57.30	167.00	227/235	100/110	150/164	188/206
777c	23.70	130.00	44.20	160.00	69.40	180.00	199/215	106/106	140/140	190/198
7921	85.67	201.00	142.20	240.00	199.50	276.00	227/231	94/106	150/158	190/224
7c30	17.93	115.00	30.00	140.00	42.20	154.00	199/215	98/106	140/144	190/198
7c46	28.61	140.00	62.10	181.00	90.10	200.00	199/267	98/106	140/144	190/198
Tank 2	Day 148	Day 148	Day 189	Day 189	Day 208	Day 208				
Tag ID	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	Soc 19	Soc 85	Soc 402	Soc 428
0052	16.31	116.00	29.00	145.00	43.50	155.00	223/267	98/106	144/148	198/210
0305	25.68	131.00	—	—	85.20	184.00	215/223	102/110	150/164	206/232

0544	12.06	108.00	25.70	135.00	39.30	149.00	231/267	98/122	144/148	194/210
075c	23.15	130.00	51.80	172.00	81.80	190.00	215/223	100/102	150/164	188/192
0903	16.79	116.00	34.00	145.00	53.90	162.00	215/223	80/100	150/164	188/206
0a17	—	—	15.30	116.00	16.60	120.00	223/235	100/106	150/152	188/188
0c6d	—	—	41.00	156.00	68.40	176.00	219/239	106/106	138/148	212/228
0d50	26.80	133.00	50.10	169.00	77.90	183.00	231/255	102/106	140/146	200/236
0f02-c	26.83	136.00	60.80	178.00	95.50	189.00	215/219	104/106	140/148	212/228
1027	14.33	111.00	29.60	144.00	44.00	156.00	223/235	100/110	150/164	206/232
1137	23.05	131.00	48.20	166.00	75.30	180.00	227/235	100/102	140/150	206/232
1158	—	—	40.00	153.00	89.00	196.00	227/235	100/102	140/150	206/232
121b	13.66	108.00	31.70	145.00	50.10	158.00	215/219	102/106	140/148	184/200
1731	25.64	135.00	47.70	169.00	77.00	188.00	215/231	102/104	146/148	184/200
1b74	21.97	129.00	46.40	166.00	76.10	187.00	227/247	106/106	140/140	222/232
1c49	17.30	117.00	31.40	144.00	48.20	161.00	223/227	96/100	146/146	188/206
1d41	22.85	132.00	54.30	164.00	85.90	189.00	231/247	100/106	140/162	174/200
2017	21.55	130.00	50.80	170.00	77.00	186.00	215/231	100/106	140/140	200/232
2068	31.66	145.00	53.60	166.00	63.70	178.00	227/231	96/118	140/152	206/206
2148	13.10	112.00	26.90	136.00	41.40	149.00	215/219	102/104	146/148	200/236
2163	18.80	123.00	42.10	156.00	62.90	175.00	219/255	102/106	140/146	188/236
2167	11.64	105.00	24.00	134.00	38.10	150.00	215/227	106/106	140/140	190/200
216f	16.08	116.00	32.70	146.00	39.60	154.00	227/247	100/114	140/162	222/232
2228	18.12	122.00	39.20	160.00	59.40	175.00	227/247	106/114	140/162	190/200
2242	20.88	125.00	36.90	156.00	52.60	166.00	219/227	106/118	140/146	188/192
2264	13.81	114.00	33.30	150.00	54.00	168.00	215/231	100/106	140/162	190/200
2329	18.90	113.00	28.40	141.00	56.50	153.00	231/267	94/106	144/148	194/210
234b	27.37	138.00	50.00	174.00	73.80	188.00	227/227	96/118	140/146	188/192
2363	12.83	110.00	20.60	129.00	28.10	137.00	227/231	100/120	146/146	188/192

247d	19.08	124.00	40.80	159.00	62.20	174.00	227/247	100/106	140/162	——
251c	19.40	125.00	39.40	159.00	56.50	170.00	231/247	100/106	140/140	222/232
2529	10.61	106.00	26.90	138.00	44.80	153.00	215/227	106/106	140/140	200/232
2728	18.74	122.00	40.40	161.00	59.50	171.00	215/227	104/106	140/146	190/200
2867	19.00	121.00	45.10	158.00	67.20	170.00	215/219	104/106	138/148	206/220
292d	——	——	20.90	126.00	27.70	135.00	227/231	94/106	150/158	194/224
2b7c	30.45	143.00	65.28	184.00	——	——	215/219	106/106	140/148	212/228
2c43	——	——	39.40	152.00	63.50	167.00	223/231	94/100	138/146	194/194
2e03	22.75	126.00	35.84	153.00	50.70	162.00	227/227	96/118	140/152	192/206
2f3f	——	——	26.00	133.00	41.30	145.00	223/235	80/100	148/150	224/232
3244	28.43	134.00	63.80	181.00	103.70	200.00	215/219	104/106	138/148	212/228
3453	17.42	116.00	29.20	140.00	42.00	145.00	231/247	94/102	140/146	194/224
3846	17.81	120.00	30.50	145.00	44.80	155.00	227/231	94/102	144/158	190/200
3b52	16.39	117.00	29.80	143.00	47.30	158.00	——	106/106	140/140	188/190
3c11	18.33	120.00	35.90	149.00	57.20	165.00	227/227	94/102	150/158	190/200
410a	22.00	130.00	55.00	174.00	85.20	188.00	223/235	80/102	148/150	188/232
4204	22.73	126.00	52.20	162.00	80.60	180.00	215/219	106/106	140/148	206/228
421c	——	——	32.90	143.00	48.60	155.00	215/219	106/106	138/148	224/232
4518	15.00	112.00	19.80	125.00	22.00	128.00	227/247	94/102	140/146	194/224
452a	19.23	125.00	39.10	160.00	59.90	175.00	223/235	102/106	148/150	188/188
4640	12.77	105.00	26.50	136.00	42.10	150.00	207/227	94/102	150/158	194/224
4702	18.88	120.00	37.90	152.00	52.10	164.00	199/267	98/106	140/148	188/210
4871	11.91	105.00	26.60	135.00	38.30	141.00	215/223	80/100	148/150	212/220
494c	22.96	130.00	50.00	172.00	82.20	185.00	215/223	102/106	148/150	188/188
495d	19.81	125.00	37.80	155.00	61.00	170.00	223/227	94/100	158/160	194/200
4b42	12.65	105.00	20.40	138.00	44.90	153.00	223/235	80/102	150/152	188/188
4c52	20.41	124.00	49.20	168.00	78.70	184.00	215/219	102/106	140/140	200/236

4d63	12.10	108.00	24.60	136.00	35.40	145.00	235/235	102/106	150/152	188/224
4f09	12.29	118.00	23.40	132.00	33.70	143.00	215/223	100/106	150/152	188/188
5043	32.44	143.00	66.40	182.00	101.40	201.00	227/235	100/110	150/164	206/232
5148	13.63	108.00	19.50	139.00	47.30	155.00	215/219	102/106	140/140	184/188
516d	—	—	32.50	148.00	48.20	160.00	199/215	106/106	140/148	188/190
5233	18.04	119.00	38.30	153.00	60.90	170.00	215/223	100/106	150/152	224/232
5356	—	—	34.60	149.00	58.20	169.00	215/223	100/100	150/164	188/206
5412	11.44	113.00	23.30	132.00	36.60	144.00	231/255	102/104	146/148	200/236
5437	22.31	127.00	40.10	154.00	48.00	159.00	215/219	—	140/148	206/220
5571	16.83	120.00	44.60	151.00	53.80	168.00	215/219	—	140/146	200/236
582d	16.88	121.00	34.00	152.00	49.00	165.00	223/231	96/100	140/152	206/206
5f5f	14.46	109.00	28.50	137.00	41.30	149.00	215/219	106/106	140/148	212/228
6169	25.02	135.00	43.50	163.00	61.80	178.00	215/239	100/108	138/144	194/210
616b	—	—	19.20	128.00	28.60	133.00	219/231	102/104	150/154	204/206
6379	22.50	129.00	34.50	153.00	44.20	160.00	215/231	106/108	138/144	194/228
643e	22.00	130.00	45.00	168.00	69.20	182.00	215/231	94/108	138/158	194/200
6468	—	—	27.40	139.00	40.00	145.00	215/239	94/98	144/148	190/194
6747	15.58	113.00	31.00	145.00	49.50	156.00	223/231	94/108	146/160	194/200
6858	19.09	117.00	40.10	154.00	—	—	227/227	94/106	146/150	190/224
6a36	19.01	120.00	31.80	146.00	43.20	155.00	219/267	98/108	140/150	190/242
6c00	18.06	119.00	42.00	157.00	61.80	173.00	223/267	106/106	140/140	190/198
6d14	22.16	124.00	56.60	168.00	82.60	184.00	215/231	106/122	144/148	194/210
6d52	16.99	116.00	29.30	144.00	47.00	155.00	223/239	106/108	138/144	194/210
703e	12.65	109.00	24.40	134.00	37.40	144.00	227/231	94/106	146/150	194/200
717f	13.76	111.00	25.10	136.00	37.00	148.00	227/231	94/102	146/150	194/224
7264	19.00	115.00	38.50	140.00	49.40	152.00	227/239	100/106	144/144	194/228
7375	—	—	28.90	141.00	43.60	156.00	231/267	94/106	140/148	194/210

7628	10.52	105.00	37.30	153.00	58.20	166.00	215/223	102/110	150/164	206/232
7648	21.42	122.00	44.70	158.00	65.90	171.00	215/223	102/110	140/150	188/206
7732	20.95	121.00	66.70	179.00	114.60	201.00	215/219	104/106	140/148	206/228
7803	22.98	127.00	60.60	169.00	104.00	190.00	219/239	104/106	140/148	206/220
7807	—	—	37.20	155.00	55.90	168.00	223/235	80/100	150/152	224/232
7a2f	19.80	119.00	39.00	145.00	49.20	148.00	219/239	106/106	140/148	212/228
7a45	22.56	127.00	46.50	158.00	75.50	174.00	215/227	100/100	140/150	206/232
7a53	—	—	18.10	125.00	23.30	133.00	223/227	118/122	146/146	188/192
7b72	12.23	107.00	24.50	135.00	37.50	146.00	235/235	80/100	148/150	224/232
7c2c	23.92	131.00	59.00	173.00	93.30	189.00	215/219	106/106	140/148	212/220
7c35	15.42	113.00	21.70	128.00	28.90	134.00	223/267	106/106	140/148	188/210
7d4d	—	—	42.50	158.00	57.60	169.00	215/219	104/106	138/148	206/228
7e6e	12.30	106.00	28.60	137.00	45.30	152.00	219/267	98/108	140/140	210/242
7f1f	22.27	129.00	50.70	170.00	80.60	192.00	227/235	100/100	150/164	188/206
7f21	—	—	34.00	150.00	49.00	155.00	227/231	118/120	140/152	188/192
7f32	18.44	116.00	45.10	153.00	65.70	165.00	215/219	104/106	138/148	206/220
Tank 3	Day 148	Day 148	Day 189	Day 189	Day 208	Day 208				
<u>Tag ID</u>	<u>W (g)</u>	<u>L (mm)</u>	<u>W (g)</u>	<u>L (mm)</u>	<u>W (g)</u>	<u>L (mm)</u>	<u>Soc 19</u>	<u>Soc 85</u>	<u>Soc 402</u>	<u>Soc 428</u>
0026(1)	15.63	113.00	43.30	151.00	71.00	169.00	219/239	104/106	140/148	206/220
0037(b)	10.61	100.00	15.60	114.00	—	—	227/227	94/106	146/150	190/224
0064	—	—	29.60	143.00	41.50	155.00	223/235	102/110	140/150	188/206
030f	29.55	140.00	58.10	180.00	86.80	196.00	215/231	102/106	140/146	184/188
0415	27.33	136.00	42.80	162.00	58.50	171.00	—	94/102	150/158	190/200
0439	—	—	51.60	170.00	78.60	187.00	215/231	102/104	140/146	200/200
0625	16.43	115.00	41.40	155.00	69.50	178.00	199/215	98/106	140/148	190/198
080d	21.63	125.00	34.30	150.00	47.40	162.00	215/231	94/108	158/160	194/200
080e	—	—	21.10	130.00	27.30	138.00	231/247	100/114	140/140	190/222

0c24	11.48	107.00	28.30	135.00	42.80	149.00	215/223	98/106	144/148	188/196
0d5c	24.65	134.00	57.20	171.00	85.60	186.00	219/239	104/106	140/148	—
0e3e	11.10	103.00	23.50	131.00	38.20	153.00	219/239	104/106	138/148	206/228
0f56	32.03	145.00	—	—	92.40	198.00	223/267	106/106	140/148	188/188
0f76	20.33	122.00	39.80	157.00	60.00	178.00	199/267	106/106	140/148	188/210
104e	19.45	122.00	50.30	160.00	78.80	180.00	215/219	106/106	138/148	212/220
114d	—	—	54.00	172.00	78.60	186.00	215/219	102/106	140/148	188/236
126d	15.06	115.00	28.70	141.00	41.10	156.00	215/223	102/106	148/150	188/224
1327	13.95	110.00	24.70	133.00	34.20	143.00	227/235	102/110	140/150	188/206
137b	11.47	104.00	19.50	125.00	26.40	133.00	235/235	100/106	148/150	188/236
1543	—	—	39.30	155.00	65.00	172.00	223/267	98/106	140/140	188/210
1554	—	—	28.40	141.00	48.10	158.00	215/227	94/108	158/160	194/200
155e	11.46	103.00	17.60	119.00	27.60	131.00	223/235	100/102	150/164	188/192
156f	19.07	123.00	37.90	155.00	48.50	164.00	199/267	98/106	140/140	198/210
1652	32.75	160.00	56.10	181.00	87.20	205.00	215/219	—	140/140	186/188
1716	—	—	24.90	137.00	30.40	141.00	223/231	94/108	138/146	194/224
171c	—	—	19.70	125.00	24.80	130.00	227/231	94/106	150/158	190/224
1776	24.42	132.00	45.60	165.00	65.40	181.00	215/223	102/110	150/164	188/192
1822	—	—	43.80	165.00	71.70	182.00	231/247	106/114	140/140	190/200
185a	11.45	105.00	20.80	130.00	30.90	140.00	223/235	100/106	148/150	188/224
1902	—	—	35.60	154.00	58.70	169.00	199/267	104/106	144/148	210/210
1951	22.11	124.00	35.10	152.00	46.90	160.00	199/267	106/106	140/148	188/190
1b12	11.79	104.00	26.50	137.00	39.20	151.00	231/255	102/104	140/146	200/236
1b43	—	—	35.80	151.00	49.80	162.00	215/231	102/104	140/140	200/236
1b57	15.45	113.00	25.60	132.00	38.50	144.00	215/231	98/122	140/148	210/212
1b65	14.41	113.00	26.90	140.00	42.80	153.00	215/223	100/100	150/164	188/192
2313	—	—	39.40	156.00	66.20	175.00	219/255	102/106	140/146	200/236



2504	22.27	129.00	38.00	155.00	59.40	174.00	223/235	100/100	140/150	192/232
2e2b	18.63	122.00	32.40	145.00	41.50	159.00	223/231	96/100	140/146	188/192
3066	18.25	122.00	25.40	139.00	35.30	145.00	227/231	100/120	140/152	188/206
3071	13.80	111.00	28.30	143.00	44.00	155.00	215/227	106/114	140/140	200/232
316e	27.01	139.00	56.90	178.00	90.50	198.00	227/247	100/114	140/140	190/200
3375	—	—	34.60	146.00	51.00	158.00	215/219	104/106	138/148	206/232
3413	15.47	118.00	—	—	40.90	152.00	231/247	100/106	140/146	190/200
353f	34.19	148.00	44.90	167.00	65.50	176.00	223/227	96/118	146/152	188/192
364c	18.21	124.00	25.00	140.00	35.10	148.00	215/227	100/104	138/146	190/194
3773	16.45	116.00	20.70	132.00	29.50	138.00	227/231	96/100	146/152	188/192
3915	20.74	127.00	35.10	154.00	49.80	164.00	223/227	100/120	140/152	192/206
3968	29.63	143.00	45.40	178.00	80.10	185.00	231/255	102/106	140/140	188/236
3a34	18.52	121.00	35.80	155.00	54.60	168.00	231/247	106/114	140/146	190/200
3a37	—	—	25.20	138.00	32.30	145.00	199/267	98/106	144/148	188/190
3c64	—	—	54.40	176.00	90.70	194.00	219/255	102/104	140/148	200/236
3d36	19.08	124.00	35.40	154.00	51.90	161.00	215/219	102/106	140/146	188/236
3e0e	21.25	127.00	30.30	146.00	42.80	154.00	227/231	116/118	140/152	192/206
4129	25.10	131.00	34.40	155.00	48.60	165.00	231/255	102/104	146/148	200/236
4269	14.19	112.00	45.50	160.00	74.80	181.00	231/255	102/104	146/148	200/236
450c	27.85	140.00	53.30	175.00	81.80	192.00	215/231	102/104	140/146	184/200
4977	26.74	136.00	61.60	177.00	95.10	193.00	219/239	106/106	138/148	212/220
4978	—	—	35.50	151.00	53.00	164.00	223/231	100/100	138/144	194/194
4a45	15.34	115.00	35.00	145.00	55.70	162.00	215/219	104/106	138/148	206/228
4b00	—	—	38.50	157.00	54.10	169.00	227/247	106/106	140/140	200/232
4d1e	—	—	24.00	134.00	32.20	142.00	207/231	94/106	150/158	190/224
4d73	—	—	33.60	147.00	55.40	165.00	231/255	102/106	140/148	184/200
4e14	10.05	96.00	18.20	122.00	25.70	130.00	207/231	94/106	144/158	190/200

4e7e	—	—	41.60	159.00	65.70	177.00	231/247	94/100	148/158	194/200
521e	14.80	120.00	31.80	148.00	43.60	157.00	223/235	80/102	148/150	188/188
5432	—	—	28.00	137.00	40.60	149.00	219/255	102/106	140/148	188/236
543b	19.82	123.00	48.20	159.00	69.20	175.00	215/219	106/106	138/148	206/228
5448	15.60	112.00	23.30	134.00	35.70	144.00	223/227	94/100	138/158	194/224
5660	—	—	28.70	140.00	43.10	155.00	207/227	94/102	144/158	194/224
567e	18.34	118.00	40.16	150.00	52.50	165.00	219/239	106/106	140/148	206/228
5814	17.54	119.00	37.80	152.00	—	—	207/227	94/102	146/150	190/224
5850	18.78	123.00	30.20	144.00	41.60	154.00	227/227	94/106	146/150	190/200
596b	10.70	101.00	—	—	29.90	135.00	235/235	100/106	150/152	188/224
5a12	14.32	112.00	—	—	41.20	153.00	227/231	94/106	144/158	190/200
5a5c	18.35	122.00	—	—	57.10	173.00	199/215	106/106	140/148	198/210
5b78	18.70	127.00	—	—	38.70	156.00	199/267	106/106	140/140	188/190
5c16	—	—	29.50	138.00	41.70	149.00	235/235	100/106	150/152	224/232
5c67	12.39	110.00	—	—	36.30	149.00	215/231	102/104	140/140	188/236
5d27	13.48	113.00	—	—	51.60	163.00	215/231	102/104	140/140	188/236
5d35	15.26	116.00	—	—	52.30	165.00	223/235	80/102	150/152	188/188
5d6b	13.27	107.00	25.00	134.00	38.60	146.00	215/231	106/122	144/148	210/212
5f16	20.00	127.00	38.90	154.00	65.30	169.00	215/223	106/106	140/140	198/210
6155	13.23	110.00	26.10	134.00	34.40	144.00	223/235	80/102	150/152	224/232
6225	17.55	117.00	42.00	155.00	67.90	170.00	219/239	106/106	138/148	206/220
641f	15.19	118.00	38.90	159.00	59.90	175.00	219/255	102/104	146/148	184/188
6465	—	—	28.60	133.00	37.40	142.00	239/267	94/98	144/148	210/212
654c	11.36	117.00	38.30	139.00	40.80	154.00	215/219	102/104	140/140	184/200
661d	14.41	115.00	34.40	135.00	35.20	150.00	223/235	80/100	148/150	224/232
6757	—	—	27.10	137.00	52.40	168.00	219/255	102/104	140/148	184/188
676c	—	—	32.90	150.00	39.90	158.00	227/247	100/106	140/140	190/200

6811	—	—	58.80	172.00	85.70	193.00	227/247	100/114	140/140	190/200
6833	13.87	113.00	39.20	147.00	48.60	163.00	215/231	102/106	140/140	188/236
683f	11.35	105.00	25.50	136.00	41.20	152.00	231/255	102/104	140/146	188/236
6a74	—	—	21.00	129.00	32.70	141.00	215/235	100/106	148/150	188/234
6d39	15.14	115.00	36.70	152.00	57.90	170.00	215/219	102/104	140/146	200/236
6d3a	—	—	48.80	168.00	68.90	182.00	215/239	100/106	144/160	194/210
6e40	—	—	21.50	127.00	30.10	135.00	235/235	80/102	150/152	188/188
7052	27.12	135.00	54.80	164.00	79.20	189.00	219/239	104/106	138/148	212/228
7813	24.70	131.00	46.80	158.00	66.40	173.00	215/219	106/106	138/148	206/220
796e	14.45	112.00	39.60	144.00	47.50	155.00	223/239	100/106	138/144	194/228
7b33	17.86	117.00	40.10	154.00	58.90	170.00	219/239	106/106	138/148	206/220
7b6b	25.76	134.00	42.00	161.00	63.10	176.00	223/227	94/108	138/158	194/200
7d00	35.23	146.00	46.70	165.00	47.50	179.00	215/231	94/100	146/160	194/200
7d74	22.31	127.00	36.40	152.00	56.70	169.00	223/227	94/108	146/160	194/200
7e2c	16.46	115.00	33.10	147.00	50.10	163.00	223/227	94/108	138/146	194/224
7f18	20.89	134.00	57.50	172.00	91.70	192.00	207/231	94/102	144/158	194/224

### APPENDIX 8a

Mean (standard deviation) and range of weight (in grams) and length (in millimeters) of experimental progeny at the first measurement period (148 days post-spawning).

Replicate tank	Family	Number of individuals	Weight (g)		Length (mm)	
			Mean (sd)	Range	Mean (sd)	Range
Tank 1	1	14	20.58 (5.90)	13.0 - 31.4	124.1 (11.1)	110 - 144
	2	10	17.91 (2.03)	15.3 - 21.5	118.9 (4.6)	112 - 125
	3	8	19.26 (3.37)	13.5 - 23.5	123.0 (8.7)	108 - 135
	4	1	---	---	---	---
	5	5	21.50 (2.72)	17.9 - 25.4	127.6 (6.0)	120 - 135
	6	7	22.93 (3.41)	16.3 - 26.5	129.0 (6.9)	117 - 137
	7	8	21.83 (5.86)	15.0 - 31.1	126.9 (11.7)	110 - 145
	8	1	---	---	---	---
	9	7	30.19 (24.78)	14.8 - 85.7	134.9 (30.1)	110 - 201
	11	0	---	---	---	---
	12	7	21.49 (6.34)	13.9 - 29.3	123.4 (12.4)	108 - 140
	13	5	23.16 (3.84)	17.9 - 28.6	129.0 (8.9)	115 - 140
Tank 2	1	8	21.76 (6.72)	10.5 - 32.4	125.9 (12.1)	105 - 143
	2	10	16.02 (4.36)	11.9 - 23.0	116.3 (9.8)	105 - 130
	3	7	21.40 (6.52)	12.8 - 31.7	126.0 (12.0)	110 - 145
	5	9	17.80 (5.57)	11.4 - 26.8	119.6 (10.1)	108 - 135
	6	10	17.63 (4.15)	10.6 - 22.9	120.5 (9.2)	105 - 132
	7	3	19.13 (3.25)	15.6 - 22.0	122.7 (8.7)	113 - 130
	8	3	21.50 (4.09)	17.0 - 25.0	126.7 (9.7)	116 - 135
	9	6	15.75 (2.96)	12.7 - 19.1	113.7 (6.3)	105 - 120
	10	1	---	---	---	---
	11	2	16.20 (1.70)	15.0 - 17.4	114.0 (2.8)	112 - 116
	12	13	22.44 (4.31)	14.5 - 30.5	125.5 (9.0)	109 - 143
	13	7	16.63 (2.36)	12.3 - 19.0	115.9 (5.0)	106 - 120
	14	3	17.73 (5.15)	12.1 - 22.2	115.0 (8.2)	108 - 124
Tank 3	1	5	17.32 (5.67)	11.5 - 24.4	117.4 (12.5)	103 - 132
	2	8	13.31 (1.85)	10.7 - 15.3	110.8 (6.8)	101 - 120
	3	6	21.60 (6.40)	16.5 - 34.2	127.0 (11.1)	116 - 148
	5	15	18.87 (7.80)	11.4 - 32.8	123.0 (16.3)	104 - 160
	6	4	18.70 (5.86)	13.8 - 27.0	122.3 (11.9)	111 - 139
	9	13	19.73 (6.98)	10.1 - 35.2	121.5 (14.5)	96 - 146
	10	1	---	---	---	---
	11	0	---	---	---	---
	12	12	19.86 (4.98)	11.1 - 27.1	122.0(10.2)	103 - 136
	13	9	19.83 (5.46)	11.5 - 32.0	123.6 (10.2)	107 - 145
	14	2	14.40 (1.56)	13.3 - 15.5	110.0 (4.2)	107 - 113

### APPENDIX 8b

Mean (standard deviation) and range of weight (in grams) and length (in millimeters) of experimental progeny at the second measurement period (189 days post-spawning).

Replicate tank	Family	Number of individuals	Weight (g)		Length (mm)	
			Mean (sd)	Range	Mean (sd)	Range
Tank 1	1	15	36.56 (12.90)	22.3 - 68.8	151.3 (16.2)	130 - 187
	2	11	36.33 (8.27)	19.5 - 47.9	149.1 (11.8)	124 - 165
	3	9	30.30 (5.36)	21.3 - 39.2	145.9 (9.7)	130 - 164
	4	1	---	---	---	---
	5	7	43.02 (8.50)	28.7 - 50.5	160.7 (10.9)	142 - 173
	6	12	44.99 (6.81)	36.4 - 56.3	162.7 (8.3)	152 - 178
	7	9	37.07 (11.55)	25.6 - 58.7	151.4 (16.4)	130 - 179
	8	1	---	---	---	---
	9	9	53.91 (34.87)	28.0 - 142.2	166.4 (30.0)	139 - 240
	11	2	32.40 (10.47)	25.0 - 39.8	144.5 (13.4)	135 - 154
	12	9	49.30 (15.17)	33.6 - 68.9	160.8 (16.1)	140 - 180
	13	6	46.97 (10.68)	30.0 - 62.1	164.5 (14.1)	140 - 181
Tank 2	1	10	45.01 (11.06)	29.6 - 66.4	160.8 (12.4)	144 - 182
	2	15	33.35 (12.16)	15.3 - 55.0	146.9 (17.2)	116 - 174
	3	9	34.94 (11.64)	18.1 - 53.6	149.9 (15.7)	125 - 174
	5	9	37.23 (11.95)	19.5 - 50.1	151.7 (14.7)	132 - 169
	6	10	38.93 (9.36)	24.0 - 54.3	155.2 (11.6)	134 - 170
	7	4	38.30 (5.76)	31.0 - 45.0	155.0 (9.6)	145 - 168
	8	3	35.77 (7.18)	29.3 - 43.5	153.3 (9.5)	144 - 163
	9	7	29.06 (6.85)	20.9 - 40.1	140.0 (9.7)	126 - 154
	10	1	---	---	---	---
	11	2	24.50 (6.65)	19.8 - 29.2	132.5 (10.6)	125 - 140
	12	16	49.21 (12.10)	28.5 - 66.7	161.8 (14.3)	137 - 184
	13	9	32.16 (5.95)	21.7 - 42.0	145.1 (8.6)	128 - 157
	14	5	33.40 (13.03)	25.7 - 56.6	144.8 (13.2)	135 - 168
Tank 3	1	6	30.40 (9.98)	17.6 - 45.6	142.5 (16.2)	119 - 165
	2	9	25.92 (5.46)	19.5 - 34.4	134.1 (7.4)	125 - 148
	3	6	31.47 (8.35)	20.7 - 44.9	147.2 (12.2)	132 - 167
	5	21	40.82 (10.43)	25.5 - 58.1	157.1 (15.6)	136 - 181
	6	8	39.51 (13.18)	21.1 - 58.8	156.3 (15.6)	130 - 178
	9	17	31.98 (11.10)	15.6 - 57.5	144.2 (15.9)	114 - 172
	10	3	41.30 (6.81)	35.5 - 48.8	154.3 (12.3)	144 - 168
	11	1	---	---	---	---
	12	13	44.43 (10.36)	23.5 - 61.6	155.5 (11.8)	131 - 177
	13	9	35.73 (5.51)	25.2 - 41.4	150.6 (8.1)	135 - 157
	14	3	26.40 (1.93)	25.0 - 28.6	133.0 (1.0)	132 - 134

### APPENDIX 8c

Mean (standard deviation) and range of weight (in grams) and length (in millimeters) of experimental progeny at the third measurement period (208 days post-spawning).

Replicate tank	Family	Number of individuals	Weight (g)		Length (mm)	
			Mean (sd)	Range	Mean (sd)	Range
Tank 1	1	15	57.21 (20.74)	32.4 - 111.1	167.4 (17.9)	139 - 205
	2	10	57.44 (14.17)	37.5 - 79.0	165.5 (12.9)	150 - 184
	3	9	41.97 (9.65)	30.0 - 60.8	156.3 (12.5)	138 - 180
	4	1	---	---	---	---
	5	7	66.87 (15.63)	40.2 - 80.6	176.6 (13.7)	152 - 189
	6	12	63.40 (12.81)	49.7 - 90.5	176.0 (11.7)	162 - 197
	7	8	53.55 (21.11)	32.9 - 91.4	165.3 (21.2)	138 - 200
	8	1	---	---	---	---
	9	9	81.32 (47.49)	44.9 - 199.5	182.6 (37.8)	154 - 276
	11	2	49.45 (20.58)	34.9 - 64.0	157.0 (21.2)	142 - 172
	12	9	73.78 (23.66)	45.6 - 113.1	178.9 (17.0)	160 - 203
	13	6	69.58 (16.34)	42.2 - 90.1	181.7 (15.5)	154 - 200
Tank 2	1	10	74.92 (17.00)	44.0 - 101.4	180.8 (14.5)	156 - 201
	2	13	49.67 (19.43)	16.6 - 85.2	157.0 (19.6)	120 - 188
	3	9	48.71 (15.59)	23.3 - 73.8	160.6 (17.5)	133 - 188
	5	9	58.41 (16.34)	36.6 - 78.7	167.1 (16.3)	144 - 188
	6	11	59.37 (15.48)	38.1 - 85.9	170.6 (13.8)	150 - 189
	7	5	60.20 (7.29)	49.5 - 69.2	169.0 (9.3)	156 - 182
	8	3	51.00 (9.46)	44.2 - 61.8	164.3 (12.1)	155 - 178
	9	6	41.03 (9.84)	27.7 - 57.2	149.5 (10.1)	135 - 165
	10	1	---	---	---	---
	11	2	32.00 (14.14)	22.0 - 42.0	136.5 (12.0)	128 - 145
	12	15	73.57 (23.59)	41.3 - 114.6	174.1 (17.3)	148 - 201
	13	8	46.29 (9.26)	28.9 - 61.8	156.4 (11.2)	134 - 173
	14	5	52.40 (18.25)	39.3 - 82.6	157.4 (15.4)	145 - 184
Tank 3	1	6	45.15 (14.56)	27.6 - 65.4	156.2 (18.7)	131 - 181
	2	11	36.21 (7.65)	26.4 - 52.3	145.9 (10.4)	133 - 165
	3	6	44.07 (12.57)	29.5 - 65.5	156.0 (13.6)	138 - 176
	5	23	60.83 (17.70)	36.3 - 90.7	171.6 (16.5)	149 - 205
	6	10	54.91 (21.11)	27.3 - 90.5	166.7 (19.2)	138 - 198
	9	16	46.11 (16.59)	24.8 - 91.7	157.4 (17.5)	130 - 192
	10	3	56.47 (11.11)	47.5 - 68.9	167.0 (13.8)	155 - 182
	11	1	---	---	---	---
	12	13	66.88 (15.64)	38.2 - 95.1	172.5 (12.0)	153 - 193
	13	12	56.43 (16.16)	32.3 - 92.4	167.6 (14.3)	145 - 198
	14	3	38.17 (0.67)	37.4 - 38.6	144.0 (2.0)	142 - 146

## APPENDIX 9

Number of families and number of progeny per mating pair (dam and sire) used in experiments to estimate heritability of cold tolerance.

<u>Brood Tank</u>	<u>Family</u>	<u>Dam (Tag ID)</u>	<u>Sire (Tag ID)</u>	<u>Number of progeny</u>
BB2	1	Dam2 (94)	Sire1 (148)	9
	2	Dam4 (144)	Sire1 (148)	19
BB7	1	Dam1 (52)	Sire1 (138)	3
	2	Dam1 (52)	Sire2 (139)	13
	3	Dam2 (88)	Sire1 (138)	35
	4	Dam2 (88)	Sire2 (139)	2
BB12	1	Dam1 (80)	Sire2 (143)	4
	2	Dam2 (90)	Sire1 (134)	1
VB3-1	1	Dam1 (77)	Sire1 (127)	13
	2	Dam1 (77)	Sire2 (132)	5
	3	Dam2 (79)	Sire1 (127)	16
	4	Dam2 (79)	Sire2 (132)	3
	5	Dam3 (95)	Sire1 (127)	13
VB3-3	1	Dam3 (90)	Sire2 (134)	31
	1	Dam1 (51)	Sire1 (53)	1
VB4-1	2	Dam2 (57)	Sire1 (53)	27
	3	Dam3 (75)	Sire1 (53)	4
Totals	17	13 Dams	9 Sires	199

### APPENDIX 10a

Genotypes of experimental fish, separated by replicate tank (1 – 3), used in cold tolerance experiments. TPWD brood tank and dam and sire (see Appendices 3 and 4) for each experimental fish are also given.

Tank 1							
<u>Tag ID</u>	<u>Soc 19</u>	<u>Soc 85</u>	<u>Soc 402</u>	<u>Soc 428</u>	<u>Brood tank</u>	<u>Dam</u>	<u>Sire</u>
1454	231/247	100/114	140/140	190/222	BB12	1	2
093a	231/247	106/114	140/140	190/200	BB12	1	2
1251	231/247	106/106	140/162	190/200	BB12	1	2
142c	231/247	106/104	140/140	222/232	BB12	1	2
443f	215/223	102/110	140/150	188/206	BB2	2	2
745D	215/223	100/102	150/164	206/232	BB2	2	2
7645	223/235	102/110	140/150	188/192	BB2	2	2
2c4d	215/235	80/100	150/152	188/232	BB2	4	2
2b74	215/223	102/106	148/150	188/232	BB2	4	2
2d05	215/235	80/102	148/150	224/232	BB2	4	2
2c14	215/223	80/102	150/152	188/220	BB2	4	2
372b	215/235	80/102	148/150	188/224	BB2	4	2
321d	215/235	100/106	150/152	188/224	BB2	4	2
3c11	219/227	100/104	140/140	192/200	BB7	1	1
0e31	227/231	118/120	140/146	188/192	BB7	1	2
0f5a	223/227	96/118	146/146	192/206	BB7	1	2
0c18	223/227	96/100	140/152	192/206	BB7	1	2
5076	223/231	100/120	140/146	188/206	BB7	1	2
1275	223/227	96/118	140/152	188/206	BB7	1	2
1448	223/227	96/118	140/152	188/192	BB7	1	2
1a60	215/231	102/106	140/140	200/236	BB7	2	1
722f	215/219	102/104	140/146	184/200	BB7	2	1
NoID6	215/219	102/104	140/146	184/200	BB7	2	1
0018	231/255	102/106	140/146	184/188	BB7	2	1
4713	215/231	102/104	146/148	188/236	BB7	2	1
656f	215/219	102/106	140/148	184/200	BB7	2	1
1a5b	231/255	102/106	140/146	184/188	BB7	2	1
2532	219/255	102/102	140/146	---	BB7	2	1
2571	219/255	102/106	140/148	184/188	BB7	2	1
6408	231/255	102/106	146/148	188/236	BB7	2	1
NoID10	215/219	102/102	140/148	188/236	BB7	2	1
032c	219/223	102/120	140/152	184/206	BB7	2	2



4e3a	215/231	94/100	158/160	194/200	VB3-1	1	1
5f1b	223/231	94/100	158/160	194/224	VB3-1	1	1
NoID2	215/231	94/108	158/160	194/200	VB3-1	1	1
4336	215/227	94/100	146/148	190/194	VB3-1	1	1
5d18	215/231	94/108	138/146	194/200	VB3-1	1	1
NoID4	215/231	106/108	138/144	194/210	VB3-1	1	2
5261	227/231	94/106	146/150	194/224	VB3-1	2	1
NoID7	227/231	94/102	150/158	194/200	VB3-1	2	1
4c3d	227/231	94/102	150/158	194/200	VB3-1	2	1
4c4d	227/227	94/102	150/158	194/194	VB3-1	2	1
685b	227/227	94/102	144/158	194/224	VB3-1	2	1
540e	207/231	94/106	144/158	194/224	VB3-1	2	1
7951	227/231	94/106	150/158	190/224	VB3-1	2	1
NoID3	207/239	100/102	144/150	194/228	VB3-1	2	2
6748	207/231	100/106	144/144	194/228	VB3-1	2	2
5b51	231/247	94/100	140/146	208/224	VB3-1	3	1
6863	231/247	94/100	148/158	194/200	VB3-1	3	1
1d0c	219/239	104/106	138/148	212/228	VB3-3	3	2
2c3d	219/239	106/106	138/148	212/228	VB3-3	3	2
151a	215/219	106/106	138/148	212/220	VB3-3	3	2
191d	219/239	106/106	138/148	206/220	VB3-3	3	2
6978	219/239	104/106	140/148	206/220	VB3-3	3	2
NoID1	215/219	108/108	138/148	212/228	VB3-3	3	2
636a	215/219	104/106	138/148	---	VB3-3	3	2
6a3e	215/219	104/106	138/148	206/218	VB3-3	3	2
6009	219/239	104/106	140/148	212/228	VB3-3	3	2
6866	219/239	106/106	140/148	206/228	VB3-3	3	2
6172	219/239	106/106	138/148	206/220	VB3-3	3	2
3c25	199/267	106/106	144/148	190/198	VB4-1	2	1
7c30	199/215	98/106	140/144	190/198	VB4-1	2	1
706a	215/223	98/106	140/144	198/210	VB4-1	2	1
4f6e	215/223	98/106	140/144	198/210	VB4-1	2	1
715d	199/215	98/106	140/144	190/198	VB4-1	2	1
7c46	199/267	98/106	140/144	190/198	VB4-1	2	1
777c	199/215	106/106	140/140	190/198	VB4-1	2	1
561a	---	---	144/148	194/210	VB4-1	3	1

## Tank 2

<u>Tag ID</u>	<u>Soc 19</u>	<u>Soc 85</u>	<u>Soc 402</u>	<u>Soc 428</u>	<u>Brood tank</u>	<u>Dam</u>	<u>Sire</u>
1359	215/219	102/106	140/148	188/236	BB12	2	1
1f05	223/235	80/102	150/152	188/232	BB2	4	1

2b3e	215/223	80/100	150/152	188/232	BB2	4	1
1d4d	235/235	80/100	148/150	188/224	BB2	4	1
2a4e	235/235	102/106	148/150	188/224	BB2	4	1
190c	223/235	80/100	150/152	188/188	BB2	4	1
NoID1	215/223	80/102	148/150	188/232	BB2	4	1
2242	219/227	106/118	140/146	188/192	BB7	1	1
397c	223/231	96/118	146/146	206/206	BB7	1	2
4257	227/231	118/120	140/146	192/206	BB7	1	2
582d	223/231	96/100	140/152	206/206	BB7	1	2
NoID3	223/231	118/120	---	---	BB7	1	2
1e01	219/255	102/106	140/140	200/236	BB7	2	1
1f59	231/255	102/104	140/148	200/236	BB7	2	1
1b38	215/231	102/104	146/148	184/188	BB7	2	1
374b	215/219	102/106	140/148	200/236	BB7	2	1
067e	215/231	102/104	140/146	184/200	BB7	2	1
0465	215/231	102/106	146/148	184/200	BB7	2	1
0168	215/231	102/106	146/148	200/236	BB7	2	1
024b	219/255	102/104	140/146	184/200	BB7	2	1
4c52	215/219	102/106	140/140	200/236	BB7	2	1
7d7e	215/219	102/104	140/146	184/200	BB7	2	1
NoID2	215/231	102/104	146/148	184/188	BB7	2	1
NoID4	215/231	102/104	140/146	200/236	BB7	2	1
NoID6	215/231	102/104	140/140	200/236	BB7	2	1
NoID7	219/255	102/104	140/140	200/236	BB7	2	1
NoID5	227/255	102/120	140/146	184/188	BB7	2	2
6f7f	215/231	94/108	146/160	---	VB3-1	1	1
6a73	215/231	94/108	138/146	194/224	VB3-1	1	1
NoID8	215/227	94/108	138/158	194/224	VB3-1	1	1
NoID9	215/227	94/100	138/158	194/200	VB3-1	1	1
6379	215/231	106/108	138/144	194/228	VB3-1	1	2
5659	227/227	94/106	144/158	194/200	VB3-1	2	1
6951	227/231	94/102	144/158	190/200	VB3-1	2	1
5a59	227/227	94/102	150/158	190/200	VB3-1	2	1
6954	207/227	94/102	144/158	194/224	VB3-1	2	1
NoID10	207/231	94/102	146/150	190/224	VB3-1	2	1
NoID12	207/231	94/106	146/150	190/224	VB3-1	2	1
7264	227/239	100/106	144/144	194/228	VB3-1	2	2
6b43	227/247	94/102	146/148	194/224	VB3-1	3	1
7836	231/247	94/102	140/146	200/208	VB3-1	3	1
740e	231/247	94/102	140/146	194/200	VB3-1	3	1

576e	227/247	94/102	140/146	200/208	VB3-1	3	1
7268	231/247	94/102	146/148	194/200	VB3-1	3	1
NoID11	227/247	94/102	140/146	194/200	VB3-1	3	1
7648	215/219	104/106	140/148	206/228	VB3-3	3	2
7d4d	215/219	104/106	138/148	206/228	VB3-3	3	2
5f5f	215/219	106/106	140/148	212/228	VB3-3	3	2
1707	219/239	106/106	140/148	212/228	VB3-3	3	2
1a11	215/219	106/106	140/148	212/220	VB3-3	3	2
2867	215/219	104/106	138/148	206/220	VB3-3	3	2
4204	215/219	106/106	140/148	206/228	VB3-3	3	2
2122	215/219	106/106	140/148	206/220	VB3-3	3	2
3244	215/219	104/106	138/148	212/228	VB3-3	3	2
2346	215/219	104/106	140/148	212/220	VB3-3	3	2
1d36	199/215	98/106	140/140	188/210	VB4-1	2	1
2649	199/267	106/106	144/148	190/198	VB4-1	2	1
4702	199/267	98/106	140/148	188/210	VB4-1	2	1
2936	223/267	106/106	140/140	190/198	VB4-1	2	1
1e3d	199/215	98/106	144/148	188/190	VB4-1	2	1
4a63	223/267	106/106	140/144	198/210	VB4-1	2	1
4814	215/223	98/106	140/144	188/190	VB4-1	2	1
4a3b	215/223	98/106	144/148	198/210	VB4-1	2	1
4671	239/267	106/122	144/148	190/212	VB4-1	3	1
410d	215/231	106/122	144/148	210/212	VB4-1	3	1
4115	215/223	98/106	140/148	188/190	VB4-1	2	1
3e1a	215/223	98/106	144/148	188/210	VB4-1	2	1
4637	215/223	98/106	144/148	188/190	VB4-1	2	1
NoID13	215/219	106/108	140/150	210/242	VB4-1	1	1
NoID14	231/267	106/122	144/148	210/212	VB4-1	3	1

## Tank 3

<u>Tag ID</u>	<u>Soc 19</u>	<u>Soc 85</u>	<u>Soc 402</u>	<u>Soc 428</u>	<u>Brood tank</u>	<u>Dam</u>	<u>Sire</u>
1776	215/223	102/110	150/164	188/192	BB2	2	1
0c17	215/223	100/102	140/150	206/232	BB2	2	1
090a	215/223	100/102	150/164	192/232	BB2	2	1
0e3c	227/235	100/110	140/150	192/232	BB2	2	1
NoID5	227/235	100/100	150/164	188/206	BB2	2	1
NoID13	227/235	100/110	140/150	192/232	BB2	2	1
137b	235/235	100/106	148/150	188/236	BB2	4	1
3764	235/235	80/102	150/152	188/224	BB2	4	1
3858	223/235	100/106	150/152	188/232	BB2	4	1
304a	223/235	80/102	150/152	188/224	BB2	4	1

3b70	223/235	80/102	148/150	224/232	BB2	4	1
2f3c	235/235	80/102	150/150	224/232	BB2	4	1
2e0b	223/235	102/108	150/154	188/188	BB2	4	1
5d2f	227/231	106/118	140/140	192/200	BB7	1	1
2e2b	223/231	96/100	140/146	188/192	BB7	1	2
3b54	223/227	96/118	140/146	206/206	BB7	1	2
NoID15	207/227	96/118	140/146	188/192	BB7	1	2
4129	231/255	102/104	146/148	200/236	BB7	2	1
3874	215/219	102/104	146/148	184/188	BB7	2	1
3d59	215/231	104/106	140/140	200/236	BB7	2	1
0a59	215/231	102/106	146/148	188/236	BB7	2	1
0c03	215/219	102/106	140/140	184/188	BB7	2	1
1225	231/255	102/106	140/148	188/236	BB7	2	1
030f	215/231	102/106	140/146	184/188	BB7	2	1
1652	215/219	102/102	140/140	---	BB7	2	1
NoID4	215/219	102/104	140/148	184/188	BB7	2	1
NoID9	231/255	102/106	140/140	184/200	BB7	2	1
080d	215/231	94/108	158/160	194/200	VB3-1	1	1
7d00	215/231	94/100	146/160	194/200	VB3-1	1	1
787d	215/231	94/100	138/146	194/200	VB3-1	1	1
7b6b	223/227	94/108	138/158	194/200	VB3-1	1	1
NoID6	215/239	100/100	144/160	194/228	VB3-1	1	2
NoID8	223/239	100/100	138/144	194/210	VB3-1	1	2
NoID12	215/239	100/106	144/160	194/210	VB3-1	1	2
5e53	227/231	94/106	144/158	190/200	VB3-1	2	1
0415	---	---	150/158	190/200	VB3-1	2	1
7a6e	227/227	114/122	146/150	190/200	VB3-1	2	1
7c10	227/247	94/102	140/158	208/224	VB3-1	3	1
0621	227/247	94/102	146/148	194/224	VB3-1	3	1
7f0c	231/247	94/100	146/148	194/224	VB3-1	3	1
NoID11	231/247	94/102	146/148	194/200	VB3-1	3	1
NoID14	231/247	94/102	146/148	194/200	VB3-1	3	1
567e	219/239	106/106	140/148	206/228	VB3-3	3	2
7813	215/219	106/106	138/148	206/220	VB3-3	3	2
0e3e	219/239	104/106	138/148	206/228	VB3-3	3	2
4a45	215/219	104/106	138/148	206/228	VB3-3	3	2
7052	219/239	104/106	138/148	212/228	VB3-3	3	2
7b33	219/239	106/106	138/148	206/220	VB3-3	3	2
104e	215/219	106/106	138/148	212/220	VB3-3	3	2
6225	219/239	106/106	138/148	206/220	VB3-3	3	2

543b	215/219	106/106	138/148	206/228	VB3-3	3	2
NoID10	219/239	106/106	138/148	206/228	VB3-3	3	2
3720	199/267	98/106	140/144	190/198	VB4-1	2	1
5b78	199/267	106/106	140/140	188/190	VB4-1	2	1
5f16	215/223	106/106	140/140	198/210	VB4-1	2	1
4f35	215/223	98/106	140/144	190/198	VB4-1	2	1
1951	199/267	106/106	140/148	188/190	VB4-1	2	1
0c24	215/223	98/106	144/148	190/198	VB4-1	2	1
0f76	199/267	106/106	140/148	188/210	VB4-1	2	1
156f	199/267	98/106	140/140	198/210	VB4-1	2	1
0f56	223/267	106/106	140/148	188/190	VB4-1	2	1

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### APPENDIX 10b

Vital statistics (duration of cold exposure (in hours); date, time, and temperature (in degrees Celsius) at death; and final weight (in grams) and length (in millimeters) at death for each experimental fish, separated by replicate tank (1 – 3) in cold tolerance experiments. Genotypes for each experimental fish (four microsatellites) may be found in Appendix 10a.

Tank 1						
<u>Tag ID</u>	<u>Duration</u>	<u>Date</u>	<u>Time</u>	<u>Temperature</u>	<u>Weight</u>	<u>Length</u>
1454	408	2/10/2004	16:30	4.8	85.8	190
093a	465	2/13/2004	9:00	4.1	118.6	203
1251	465	2/13/2004	9:00	4.1	93.0	192
142c	479	2/13/2004	16:00	3.0	170.8	242
443f	489	2/14/2004	9:00	3.1	68.4	178
745D	515	2/15/2004	10:00	3.0	99.5	206
7645	529	2/15/2004	17:00	3.0	116.0	211
2c4d	467	2/13/2004	10:00	2.8	92.0	197
2b74	489	2/14/2004	9:00	3.1	56.2	164
2d05	489	2/14/2004	9:00	3.1	81.2	182
2c14	515	2/15/2004	10:00	3.0	102.8	195
372b	515	2/15/2004	10:00	3.0	73.2	170
321d	529	2/15/2004	17:00	3.0	57.9	164
3c11	529	2/15/2004	17:00	3.0	115.4	206
0e31	455	2/12/2004	16:00	3.5	68.0	181
0f5a	465	2/13/2004	9:00	4.1	60.9	178
0c18	479	2/13/2004	16:00	3.0	57.0	168
5076	489	2/14/2004	9:00	3.1	85.5	186
1275	515	2/15/2004	10:00	3.0	87.6	200
1448	529	2/15/2004	17:00	3.0	54.4	170
1a60	442	2/12/2004	9:30	4.0	39.5	150
722f	465	2/13/2004	9:00	4.1	96.5	200
NoID6	504	2/14/2004	16:30	2.6	81.2	191
0018	515	2/15/2004	10:00	3.0	63.2	170
4713	515	2/15/2004	10:00	3.0	128.5	218
656f	529	2/15/2004	17:00	3.0	78.2	185
1a5b	536.5	2/16/2004	8:45	2.3	72.0	175
2532	536.5	2/16/2004	8:45	2.3	77.1	183
2571	536.5	2/16/2004	8:45	2.3	98.2	196
6408	555	2/16/2004	18:00	3.1	125.9	216

NoID10	584.5	2/18/2004	8:45	2.6	97.7	198
032c	515	2/15/2004	10:00	3.0	73.2	186
4e3a	442	2/12/2004	9:30	4.0	80.5	192
5f1b	455	2/12/2004	16:00	3.5	89.5	198
NoID2	455	2/12/2004	16:00	3.5	78.5	184
4336	515	2/15/2004	10:00	3.0	102.4	204
5d18	515	2/15/2004	10:00	3.0	185.9	250
NoID4	467	2/13/2004	10:00	2.8	45.3	155
5261	489	2/14/2004	9:00	3.1	107.5	199
NoID7	504	2/14/2004	16:30	2.6	56.6	164
4c3d	515	2/15/2004	10:00	3.0	119.0	204
4c4d	515	2/15/2004	10:00	3.0	82.7	185
685b	515	2/15/2004	10:00	3.0	64.9	170
540e	536.5	2/16/2004	8:45	2.3	125.0	210
7951	585	2/18/2004	9:00	2.8	284.1	303
NoID3	479	2/13/2004	16:00	3.0	80.8	190
6748	489	2/14/2004	9:00	3.1	59.1	168
5b51	455	2/12/2004	16:00	3.5	42.8	145
6863	515	2/15/2004	10:00	3.0	66.4	170
1d0c	442	2/12/2004	9:30	4.0	77.3	177
2c3d	442	2/12/2004	9:30	4.0	64.8	164
151a	489	2/14/2004	9:00	3.1	85.0	192
191d	489	2/14/2004	9:00	3.1	69.8	178
6978	489	2/14/2004	9:00	3.0	156.3	223
NoID1	489	2/14/2004	9:00	3.1	52.9	159
636a	504	2/14/2004	16:30	2.6	87.4	179
6a3e	504	2/14/2004	16:30	2.6	111.3	204
6009	515	2/15/2004	10:00	3.0	107.7	204
6866	515	2/15/2004	10:00	3.0	171.0	222
6172	555	2/16/2004	18:00	3.1	236.5	256
3c25	442	2/12/2004	9:30	4.0	50.4	162
7c30	467	2/13/2004	10:00	2.8	100.1	196
706a	479	2/13/2004	16:00	3.0	131.8	222
4f6e	504	2/14/2004	16:30	2.6	222.3	253
715d	515	2/15/2004	10:00	3.0	157.3	230
7c46	515	2/15/2004	10:00	3.0	194.4	247
777c	529	2/15/2004	17:00	3.0	147.7	225
561a	442	2/12/2004	9:30	4.0	48.0	161

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**Tank 2**


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<u>Tag ID</u>	<u>Duration</u>	<u>Date</u>	<u>Time</u>	<u>Temperature</u>	<u>Weight</u>	<u>Length</u>
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1359	465	2/13/2004	9:00	4.3	45.9	159
1f05	521	2/15/2004	17:00	3.2	89.4	187
2b3e	521	2/15/2004	17:00	3.2	85.9	197
1d4d	546.25	2/16/2004	18:15	3.4	58.0	163
2a4e	633	2/20/2004	9:00	4.8	92.6	193
190c	641	2/20/2004	17:00	3.2	58.3	171
NoID1	561	2/17/2004	9:00	3.0	56.0	159
2242	514	2/15/2004	10:00	3.2	118.1	211
397c	514	2/15/2004	10:00	3.2	43.6	152
4257	537	2/16/2004	9:00	2.4	56.3	167
582d	537	2/16/2004	9:00	2.4	89.3	205
NoID3	561	2/17/2004	9:00	3.0	50.8	163
1e01	609	2/19/2004	9:00	3.0	81.6	191
1f59	609.5	2/19/2004	9:30	3.0	65.8	170
1b38	465	2/13/2004	9:00	4.3	281.2	285
374b	466	2/13/2004	10:00	4.3	62.5	172
067e	497.5	2/14/2004	17:30	2.7	54.4	165
0465	497.5	2/14/2004	17:30	2.8	63.7	175
0168	514	2/15/2004	10:00	3.0	62.6	167
024b	521	2/15/2004	17:00	3.2	51.9	162
4c52	561	2/17/2004	9:00	3.0	160.3	230
7d7e	472	2/13/2004	16:00	3.0	91.8	201
NoID2	514	2/15/2004	10:00	3.2	57.8	172
NoID4	521	2/15/2004	17:00	3.2	60.7	172
NoID6	537	2/16/2004	9:00	2.4	67.2	170
NoID7	609	2/19/2004	9:00	3.0	64.4	172
NoID5	609.5	2/19/2004	9:30	3.0	102.2	200
6f7f	473.5	2/13/2004	17:30	3.0	74.2	184
6a73	490	2/14/2004	10:00	3.4	88.3	195
NoID8	497.5	2/14/2004	17:30	2.7	55.5	168
NoID9	497.5	2/14/2004	17:30	2.7	60.3	176
6379	514	2/15/2004	10:00	3.2	75.5	184
5659	521	2/15/2004	17:00	3.2	69.4	173
6951	537	2/16/2004	9:00	2.4	62.0	157
5a59	466	2/13/2004	10:00	2.8	48.8	156
6954	497.5	2/14/2004	17:30	2.7	160.3	220
NoID10	514	2/15/2004	10:00	3.0	75.6	177
NoID12	521	2/15/2004	17:00	3.2	70.3	175
7264	609	2/19/2004	9:00	3.0	115.3	192
6b43	609.5	2/19/2004	9:30	3.0	48.2	150



7836	465	2/13/2004	9:00	4.3	71.9	177
740e	490	2/14/2004	10:00	3.4	52.5	157
576e	514	2/15/2004	10:00	3.2	69.6	168
7268	514	2/15/2004	10:00	3.2	51.0	158
NoID11	537	2/16/2004	9:00	2.4	44.3	154
7648	490	2/14/2004	10:00	3.4	105.8	197
7d4d	584.75	2/18/2004	8:45	2.7	45.5	150
5f5f	514	2/15/2004	10:00	3.0	78.0	178
1707	466	2/13/2004	10:00	2.8	50.7	150
1a11	488.5	2/14/2004	8:30	2.4	72.4	174
2867	497.5	2/14/2004	17:30	2.7	116.8	200
4204	497.5	2/14/2004	17:30	2.7	135.4	206
2122	514	2/15/2004	10:00	3.2	50.3	150
3244	514	2/15/2004	10:00	3.2	200.9	240
2346	536.75	2/16/2004	8:45	2.4	103.3	196
1d36	465	2/13/2004	9:00	4.3	78.3	185
2649	466	2/13/2004	10:00	2.8	119.2	208
4702	497.5	2/14/2004	17:30	2.7	110.1	200
2936	514	2/15/2004	10:00	3.2	73.0	183
1e3d	521	2/15/2004	17:00	3.2	77.9	185
4a63	441.5	2/12/2004	9:30	3.8	95.1	201
4814	465	2/13/2004	9:00	4.3	54.2	165
4a3b	465	2/13/2004	9:00	4.3	134.1	220
4671	490	2/14/2004	10:00	3.4	46.7	152
410d	497.5	2/14/2004	17:30	2.7	106.1	198
4115	497.5	2/14/2004	17:30	2.7	62.2	174
3e1a	514	2/15/2004	10:00	3.0	105.0	205
4637	521	2/15/2004	17:00	3.2	94.6	194
NoID13	478	2/13/2004	22:00	2.8	58.9	167
NoID14	490	2/14/2004	10:00	3.4	47.5	157
Tank 3						
<u>Tag ID</u>	<u>Duration</u>	<u>Date</u>	<u>Time</u>	<u>Temperature</u>	<u>Weight</u>	<u>Length</u>
1776	521	2/15/2004	17:00	3.5	127.0	217
0c17	514	2/15/2004	10:00	3.0	52.2	163
090a	521	2/15/2004	17:00	3.5	96.2	196
0e3c	537	2/16/2004	9:00	2.7	45.7	156
NoID5	490.5	2/14/2004	10:30	2.9	40.2	151
NoID13	537	2/16/2004	9:00	2.7	50.3	159
137b	465	2/13/2004	9:00	3.7	42.4	155
3764	490	2/14/2004	10:00	3.0	53.7	167

3858	498	2/14/2004	18:00	2.8	93.1	189
304a	514	2/15/2004	10:00	3.0	51.0	163
3b70	514	2/15/2004	10:00	3.0	47.4	155
2f3c	537	2/16/2004	9:00	2.7	68.8	173
2e0b	609.5	2/19/2004	9:30	3.2	120.0	210
5d2f	537	2/16/2004	9:00	2.7	44.6	156
2e2b	521	2/15/2004	17:00	3.5	97.1	200
3b54	466	2/13/2004	10:00	3.0	70.5	180
NoID15	537	2/16/2004	9:00	2.7	56.6	170
4129	537	2/16/2004	9:00	2.7	83.3	192
3874	465	2/13/2004	9:00	3.7	64.6	173
3d59	561	2/17/2004	9:00	3.5	55.9	164
0a59	465	2/13/2004	9:00	3.7	47.5	156
0c03	514	2/15/2004	10:00	3.0	57.2	174
1225	561	2/17/2004	9:00	3.5	45.1	156
030f	561	2/17/2004	9:00	3.5	170.3	240
1652	537	2/16/2004	9:00	2.7	164.6	245
NoID4	490.5	2/14/2004	10:30	2.9	55.7	165
NoID9	498	2/14/2004	18:00	2.8	68.1	179
080d	490.5	2/14/2004	10:30	2.9	100.9	201
7d00	498	2/14/2004	18:00	2.8	125.4	215
787d	514	2/15/2004	10:00	3.0	69.9	180
7b6b	537	2/16/2004	9:00	2.4	124.9	219
NoID6	466	2/13/2004	10:00	3.0	35.6	144
NoID8	498	2/14/2004	18:00	2.8	59.0	165
NoID12	521	2/15/2004	17:00	3.5	47.9	157
5e53	514	2/15/2004	10:00	3.0	74.4	177
0415	561	2/17/2004	9:00	3.5	95.8	199
7a6e	514	2/15/2004	10:00	3.0	31.4	136
7c10	498	2/14/2004	18:00	2.8	33.8	137
0621	514	2/15/2004	10:00	3.0	29.3	136
7f0c	537	2/16/2004	9:00	2.7	42.9	146
NoID11	514	2/15/2004	10:00	3.0	45.8	151
NoID14	537	2/16/2004	9:00	2.7	48.2	153
567e	473.5	2/13/2004	17:30	3.2	84.2	183
7813	473.5	2/13/2004	17:30	3.2	95.2	189
0e3e	498	2/14/2004	18:00	2.8	75.8	178
4a45	514	2/15/2004	10:00	3.0	108.3	190
7052	514	2/15/2004	10:00	3.0	114.5	196
7b33	514	2/15/2004	10:00	3.0	116.8	205

104e	537	2/16/2004	9:00	2.7	140.6	211
6225	537	2/16/2004	9:00	2.7	141.7	211
543b	546.5	2/16/2004	18:30	3.8	149.3	211
NoID10	490	2/14/2004	10:00	3.0	99.6	195
3720	490.5	2/14/2004	10:30	2.9	87.5	176
5b78	490.5	2/14/2004	10:30	2.9	73.1	188
5f16	514	2/15/2004	10:00	3.0	118.9	211
4f35	465	2/13/2004	9:00	3.7	36.1	146
1951	473.5	2/13/2004	17:30	3.2	70.8	177
0c24	490.5	2/14/2004	10:30	2.9	80.4	179
0f76	490.5	2/14/2004	10:30	2.9	132.1	210
156f	514	2/15/2004	10:00	3.0	106.3	200
0f56	537	2/16/2004	9:00	2.7	194.8	246

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## APPENDIX 11

Death statistics of fishes in each of three replicate tanks (1-3).

<u>Replicate</u>	<u>Time of death (hours)</u>	<u>Temperature at death (<math>^{\circ}\text{C}</math>)</u>	<u>Number of fish</u>
I	105	10	1
	408	4.8	1
	442	4	6
	455	3.5	4
	465	4.1	4
	467	2.8	3
	479	3	4
	488.5	2.3	1
	489	3.1	10
	504	2.6	6
	505	3	1
	515	3	17
	529	3	7
	536.5	2.3	4
	555	3.1	2
	584.5	2.6	1
II	441.5	3.8	1
	465	4.3	6
	466	2.8	4
	472	3	1
	473.5	3	1
	478	2.8	1
	488.5	2.4	1
	490	3.4	5
	497.5	2.7	10
	514	3.2	13
	521	3.2	8
	536.75	2.4	1
	537	2.4	5
	546.25	3.4	1
	561	3	3
	584.75	2.7	1

	609	3	2
	609.5	3	2
	633	4.8	1
	641	3.2	1
III	321	7	1
	465	3.7	4
	466	3	2
	473.5	3.2	3
	490	3	2
	490.5	2.9	7
	498	2.8	6
	514	3	14
	521	3.5	4
	537	2.7	13
	546.5	3.8	1
	561	3.5	4
	609.5	3.2	1

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### APPENDIX 12a

Genotypes at 31 microsatellites for dam, sire, and offspring in each of two families used in testing Mendelian segregation and independent assortment

<u>Family 1</u>	<u>Soc 11</u>	<u>Soc 19</u>	<u>Soc 44</u>	<u>Soc 60</u>	<u>Soc 83</u>	<u>Soc 85</u>	<u>Soc 99</u>
Dam	218/226	219/247	245/259	158/164	122/134	100/102	176/192
Sire	218/228	239/247	217/229	158/164	120/122	98/106	166/176
1	218/226	219/239	229/245	158/164	122/134	98/100	176/192
2	218/226	219/239	217/245	158/158	122/134	102/106	176/176
3	218/218	219/247	229/245	158/164	122/134	100/106	176/176
4	218/218	247/247	217/259	164/164	120/134	98/100	176/192
5	226/228	247/247	217/259	158/164	120/134	98/100	166/176
6	218/218	219/239	217/245	158/164	122/122	102/106	166/176
7	226/228	247/247	217/245	164/164	120/122	102/106	176/192
8	226/228	239/247	229/245	158/164	122/134	98/100	166/176
9	218/228	219/239	217/245	158/158	122/134	100/106	166/176
10	226/228	219/247	229/245	158/164	122/134	100/106	166/176
11	226/228	239/247	229/245	158/164	122/122	98/102	166/176
12	218/226	239/247	217/259	158/158	122/122	100/106	176/192
13	218/228	219/239	229/259	164/164	122/122	100/106	176/192
14	218/226	247/247	217/259	164/164	122/134	98/106	166/176
15	218/228	219/247	229/245	158/164	120/122	98/100	176/176
16	218/218	219/247	229/259	158/164	122/134	98/100	176/176
17	226/228	219/239	217/259	164/164	122/134	98/100	166/192
18	218/228	247/247	217/259	158/164	122/134	102/106	166/176
19	218/218	247/247	217/259	158/164	120/134	102/106	166/176
20	218/218	219/247	229/259	158/164	120/134	102/106	176/176
21	226/228	219/239	229/259	158/158	120/122	98/102	176/192
22	218/226	247/247	229/245	158/164	122/134	98/102	166/176
23	----	----	----	----	----	----	176/176
24	218/228	219/247	229/259	158/164	122/134	98/102	176/176
25	218/226	219/247	229/259	164/164	122/134	102/106	166/176
26	218/226	239/247	229/259	158/164	120/134	98/100	176/176
27	226/228	219/239	229/245	164/164	120/122	102/106	166/192
28	218/218	219/247	217/259	158/164	122/122	100/106	166/176
29	218/228	219/247	217/259	158/164	120/134	100/106	166/176
30	218/226	239/247	217/259	158/164	120/134	100/106	176/192
31	218/228	247/247	217/245	158/164	120/122	98/102	166/192
32	218/218	247/247	217/245	158/158	120/134	98/102	176/192
33	218/218	219/239	229/259	164/164	120/134	98/100	166/176

34	218/218	219/247	229/259	158/164	120/122	100/106	176/176
35	218/228	219/239	229/245	164/164	120/122	100/106	166/192
36	226/228	219/247	229/245	158/164	120/122	98/100	166/192
37	218/218	247/247	217/245	164/164	122/122	102/106	176/176
38	218/226	247/247	229/259	158/158	122/122	98/100	176/176
39	226/228	239/247	217/245	164/164	120/134	102/106	166/176
40	218/226	219/247	229/259	158/158	120/134	102/106	176/192
41	226/228	247/247	217/245	158/164	122/134	100/106	166/176
42	226/228	247/247	217/245	164/164	120/134	100/106	166/192
43	218/226	239/247	229/259	158/158	120/134	98/100	166/176
44	218/218	247/247	217/259	158/158	122/122	100/106	166/192
45	226/228	219/239	229/245	158/164	122/122	98/102	176/176
46	218/226	239/247	217/245	164/164	120/134	98/100	176/192
47	218/228	219/239	217/245	----	122/122	100/106	176/176
48	226/228	219/239	217/259	----	122/122	98/102	166/176
49	----	219/239	229/259	158/164	120/134	98/100	166/192
50	218/228	219/247	229/245	158/158	120/122	102/106	176/176
51	218/228	219/239	217/259	164/164	122/134	98/100	166/176
52	218/226	219/247	217/259	158/158	122/134	98/100	176/176
53	----	219/239	229/259	158/164	122/134	98/102	176/176
54	218/218	219/247	229/259	158/164	120/122	100/106	176/192
55	218/226	219/247	229/245	158/158	120/122	100/106	166/192
56	218/218	219/247	229/245	164/164	120/122	102/106	166/192
57	----	247/247	229/245	158/158	120/122	98/100	176/192
58	218/228	239/247	229/259	158/164	122/122	98/100	166/192
59	218/218	219/239	----	158/164	122/134	102/106	176/176
60	218/226	219/239	217/259	158/158	122/134	102/106	166/176
61	218/228	239/247	217/259	158/164	120/122	98/100	176/192
62	226/228	219/239	217/259	158/158	120/134	100/106	166/192
63	226/228	219/239	217/259	164/164	122/122	100/106	176/176
64	218/226	219/239	229/245	158/164	120/122	98/100	166/176
65	218/228	219/247	217/259	164/164	120/122	102/106	166/176
66	226/228	219/247	217/259	158/164	120/122	102/106	166/192
67	218/226	219/239	217/245	158/158	120/134	98/102	166/192
68	226/228	239/247	217/245	158/164	120/122	100/106	176/176
69	218/226	219/247	217/259	158/164	120/122	98/100	176/176
70	218/218	219/239	229/245	158/164	120/122	100/106	176/176
71	226/228	219/239	229/259	158/164	122/134	----	176/192
72	218/226	247/247	229/245	158/164	120/134	98/100	166/176
73	218/218	219/247	229/245	164/164	120/122	102/106	166/192

74	218/226	247/247	229/259	158/164	122/122	98/100	176/192
75	----	247/247	229/245	158/164	122/134	98/106	166/192
76	218/218	239/247	217/245	158/164	122/134	98/100	176/192
77	218/218	247/247	----	158/164	122/122	98/102	176/176
78	218/228	219/239	217/245	158/164	122/122	98/100	176/192
79	218/218	219/247	217/259	158/158	122/122	102/106	176/192
80	226/228	239/247	217/259	164/164	120/122	102/106	176/176
81	226/228	239/247	229/245	164/164	120/122	102/106	166/192
82	226/228	219/247	229/259	158/164	122/134	98/102	166/192
83	226/228	239/247	217/259	158/164	122/134	98/100	166/176
84	218/218	219/247	217/245	158/164	120/134	100/106	166/176
85	218/228	239/247	217/245	158/158	122/122	102/106	166/192
86	218/218	219/239	229/245	164/164	120/134	98/102	166/192
87	226/228	219/239	217/245	158/164	120/134	102/106	176/176
88	218/226	219/247	217/245	158/164	122/134	102/106	176/192
89	----	247/247	229/245	158/158	122/122	100/106	166/176
90	218/218	219/247	229/245	158/164	120/134	98/100	166/192
91	218/218	219/239	217/259	158/158	120/134	100/106	166/176
92	218/230	211/215	251/261	158/162	120/120	100/114	176/188
93	218/218	219/247	217/245	158/158	120/134	98/102	176/176
94	218/226	239/247	217/259	158/164	120/122	100/106	176/192
95	226/228	239/247	217/245	158/164	122/122	98/102	166/176
96	218/218	239/247	229/259	158/164	120/134	100/106	166/176
97	218/218	247/247	----	158/158	122/122	102/106	166/176
98	218/228	239/247	217/245	158/164	120/134	98/102	166/176
99	218/226	219/239	217/259	158/164	122/122	100/106	166/192
100	226/228	247/247	217/245	158/158	122/134	98/102	166/176
101	226/228	239/247	229/245	158/158	120/122	100/106	176/192
102	218/218	239/247	217/259	158/164	120/122	98/102	166/176
103	218/228	219/239	217/245	158/164	122/134	98/102	176/176
104	218/226	239/247	229/259	158/164	122/122	102/106	176/176
105	218/228	219/247	----	158/164	120/122	102/106	176/192
106	218/218	239/247	217/245	164/164	120/122	98/100	166/192
107	218/228	219/247	229/259	158/164	120/122	100/106	----
108	226/226	247/247	217/259	164/164	120/134	100/106	166/176
109	218/226	247/247	229/259	164/164	120/122	100/106	166/192
110	218/226	239/247	217/245	158/164	122/122	98/102	166/176
111	226/226	239/247	229/259	158/164	120/134	98/100	166/176
112	218/218	239/247	229/245	158/158	120/134	100/106	166/192
113	218/226	239/247	217/245	164/164	122/122	98/102	176/192



114	226/226	239/247	217/259	158/158	122/122	98/100	166/176
115	218/226	239/247	229/245	164/164	122/122	100/106	166/192
116	218/226	219/247	----	158/164	122/134	102/106	176/176
117	226/226	239/247	229/245	164/164	120/134	98/100	166/176
118	218/226	247/247	217/259	158/164	122/134	100/106	176/192
119	218/226	219/239	217/245	158/164	122/134	102/106	166/176
120	218/226	247/247	229/245	158/164	122/134	102/106	166/192
121	218/226	----	----	158/164	122/134	----	166/176
122	218/228	239/247	----	164/164	120/122	98/100	176/176
123	226/226	219/247	229/259	158/164	122/134	102/106	176/192
124	218/228	247/247	----	158/164	122/122	100/106	166/176
125	226/226	219/247	217/259	164/164	122/122	98/102	166/176
126	218/218	219/247	217/245	158/164	122/134	98/102	----
<u>Family 2</u>	<u>Soc 11</u>	<u>Soc 19</u>	<u>Soc 44</u>	<u>Soc 60</u>	<u>Soc 83</u>	<u>Soc 85</u>	<u>Soc 99</u>
Dam	218/218	219/219	265/265	161/161	126/130	104/106	178/192
Sire	218/228	215/239	217/235	158/158	120/122	106/106	176/200
1	218/228	219/239	217/265	158/161	120/126	104/106	192/200
2	218/218	215/219	217/265	158/161	120/130	104/106	192/200
3	218/218	219/239	217/265	158/161	122/130	106/106	176/178
4	218/228	219/239	235/265	158/161	120/130	104/106	192/200
5	218/228	215/219	235/265	158/161	122/130	106/106	178/200
6	218/218	215/219	235/265	158/161	122/130	104/106	178/200
7	218/218	219/239	217/265	158/161	120/130	106/106	192/200
8	218/228	215/219	235/265	158/161	120/130	104/106	192/200
9	218/228	219/239	217/265	158/161	120/130	104/106	176/178
10	218/218	215/219	217/265	158/161	122/130	104/106	192/200
11	----	215/219	----	----	----	106/106	----
12	218/228	219/239	235/265	158/161	122/126	106/106	176/178
13	218/218	215/219	235/265	158/161	122/130	106/106	192/200
14	218/228	215/219	217/265	158/161	120/130	106/106	176/178
15	218/218	219/239	235/265	158/161	120/130	106/106	176/178
16	218/218	219/239	235/265	158/161	120/130	106/106	176/192
17	218/218	215/219	217/265	158/161	122/130	106/106	178/200
18	218/218	219/239	217/265	158/161	120/126	104/106	176/178
19	218/218	219/239	217/265	158/161	122/130	104/106	176/178
21	218/218	219/239	235/265	158/161	122/130	106/106	176/178
22	218/218	219/239	217/265	158/161	122/130	104/106	176/192
23	218/228	219/239	235/265	158/161	120/126	104/106	176/192
24	218/218	215/219	235/265	158/161	120/126	104/106	192/200
25	218/218	219/239	217/265	158/161	122/130	106/106	176/178

26	218/218	215/219	217/265	158/161	122/126	104/106	176/192
27	----	215/219	217/265	158/161	----	106/106	----
28	218/228	215/219	235/265	158/161	120/126	104/106	178/200
29	218/228	215/219	235/265	158/161	120/130	104/106	176/192
30	218/228	215/219	235/265	158/161	120/130	106/106	178/200
31	218/218	219/239	217/265	158/161	122/126	104/106	176/192
32	218/218	215/219	235/265	158/161	120/126	106/106	176/192
33	218/228	219/239	217/265	158/161	122/126	106/106	176/178
34	218/228	215/219	235/265	158/161	120/126	104/106	176/192
35	218/228	219/239	235/265	158/161	----	104/106	176/192
36	218/218	219/239	235/265	158/161	122/126	104/106	176/192
37	218/228	215/219	217/265	158/161	120/126	106/106	178/200
38	218/218	219/239	235/265	158/161	120/126	104/106	192/200
39	218/228	215/219	217/265	158/161	120/130	106/106	176/192
40	218/228	219/239	235/265	158/161	120/126	104/106	178/200
41	218/218	215/219	235/265	158/161	120/130	104/106	178/200
42	218/218	215/219	217/265	158/161	120/130	106/106	176/192
43	218/218	215/219	235/265	158/161	120/126	106/106	176/178
44	218/228	215/219	217/265	158/161	120/126	104/106	176/178
45	218/218	215/219	235/265	158/161	122/126	106/106	176/192
46	218/218	215/219	235/265	158/161	120/126	106/106	176/192
47	218/228	215/219	235/265	158/161	120/126	104/106	192/200
48	218/228	215/219	235/265	158/161	120/130	104/106	178/200
49	218/218	219/239	----	158/161	120/126	104/106	176/178
50	218/228	219/239	217/265	158/161	120/126	106/106	176/178
51	218/218	219/239	217/265	158/161	120/126	106/106	176/178
52	218/218	219/239	217/265	158/161	122/126	104/106	176/192
53	218/218	215/219	217/265	158/161	122/130	104/106	192/200
54	218/218	215/219	235/265	158/161	122/126	104/106	176/192
55	218/218	215/219	235/265	158/161	120/130	104/106	192/200
56	218/228	215/219	235/265	158/161	122/126	104/106	176/178
57	218/218	219/239	235/265	158/161	122/130	104/106	178/200
58	218/228	219/239	217/265	158/161	120/126	106/106	178/200
59	218/228	215/219	235/265	158/161	120/126	104/106	176/178
60	218/218	219/239	235/265	158/161	120/130	104/106	178/200
61	218/228	219/239	235/265	158/161	120/130	104/106	192/200
62	218/218	219/239	235/265	158/161	122/130	104/106	178/200
63	218/228	219/239	235/265	158/161	122/126	104/106	176/192
64	218/218	219/239	235/265	158/161	120/126	104/106	176/178
65	218/218	215/219	235/265	158/161	122/130	106/106	192/200

66	218/218	215/219	235/265	158/161	122/126	104/106	178/200
67	218/218	215/219	235/265	158/161	122/130	104/106	176/178
68	218/218	219/239	235/265	158/161	122/130	106/106	178/200
69	218/228	215/219	235/265	158/161	122/130	106/106	176/178
70	218/218	219/239	235/265	158/161	120/130	106/106	176/192
71	218/218	215/219	235/265	158/161	120/126	104/106	192/200
72	218/228	219/239	217/265	158/161	120/126	104/106	192/200
73	218/228	215/219	235/265	158/161	122/126	104/106	176/178
74	218/218	215/219	217/265	158/161	120/130	104/106	178/200
75	218/218	215/219	235/265	158/161	122/126	106/106	176/192
76	218/218	219/239	235/265	158/161	122/126	106/106	178/200
77	218/218	215/219	217/265	158/161	120/126	106/106	176/192
78	218/228	215/219	235/265	158/161	120/130	104/106	192/200
79	218/228	215/219	217/265	158/161	122/126	106/106	192/200
80	218/228	219/239	217/265	158/161	122/126	106/106	178/200
81	218/218	219/239	235/265	158/161	122/126	106/106	192/200
82	218/218	219/239	235/265	158/161	122/126	104/106	178/200
83	218/228	219/239	215/265	158/161	120/130	106/106	192/200
84	218/218	215/219	235/265	158/161	120/130	104/106	192/200
85	218/218	215/219	217/265	158/161	122/130	104/106	192/200
86	218/218	215/219	235/265	158/161	120/130	104/106	176/192
87	218/218	215/219	235/265	158/161	122/130	106/106	176/192
88	218/218	219/239	217/265	158/161	120/126	104/106	178/200
89	218/218	219/239	235/265	158/161	120/126	106/106	176/192
90	218/218	215/219	235/265	158/161	120/130	104/106	192/200
91	218/218	215/219	235/265	158/161	122/126	104/106	178/200
92	218/218	215/219	235/265	158/161	120/130	106/106	178/200
93	218/218	219/239	217/265	158/161	120/126	104/106	192/200
94	218/218	215/219	235/265	158/161	122/130	106/106	176/192
95	218/218	215/219	217/265	158/161	122/126	106/106	176/178
96	218/218	215/219	217/265	158/161	120/130	104/106	176/192
97	218/228	219/239	235/265	158/161	120/130	106/106	178/200
98	218/228	219/239	235/265	158/161	120/126	104/106	176/178
99	218/218	219/239	235/265	158/161	122/130	104/106	176/192
100	218/228	215/219	217/265	158/161	122/126	106/106	178/200
101	218/218	215/219	217/265	158/161	120/126	106/106	178/200
102	218/228	219/239	235/265	158/161	120/126	104/106	192/200
103	218/218	215/219	217/265	158/161	122/126	104/106	176/178
104	218/218	215/219	217/265	158/161	120/126	104/106	178/200
105	218/228	215/219	217/265	158/161	120/130	106/106	176/178

106	218/228	215/219	235/265	158/161	120/126	106/106	176/192
107	218/228	215/219	235/265	158/161	122/130	106/106	176/178
108	218/228	219/239	217/265	158/161	122/130	104/106	176/192
109	218/228	215/219	217/265	158/161	122/130	104/106	176/192
110	218/228	219/239	235/265	158/161	122/126	104/106	176/192
111	218/228	215/219	235/265	158/161	122/126	104/106	176/178
112	218/228	219/239	235/265	158/161	122/130	104/106	176/192
113	218/218	219/239	217/265	158/161	120/130	104/106	192/200
114	218/228	219/239	235/265	158/161	120/126	106/106	178/200
115	218/228	215/219	235/265	158/161	120/130	104/106	178/200
116	218/218	219/239	235/265	158/161	122/126	106/106	176/192
117	218/218	215/219	235/265	158/161	122/126	106/106	176/178
118	218/218	219/239	235/265	158/161	120/126	104/106	176/178
119	218/218	219/239	217/265	158/161	120/130	106/106	176/192
120	218/218	219/239	217/265	158/161	120/130	106/106	176/192
121	218/218	215/219	217/265	158/161	120/126	104/106	176/192
122	218/218	219/239	217/265	158/161	122/130	106/106	176/178
123	218/228	215/219	217/265	158/161	----	104/106	----

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## APPENDIX 12b

Genotypes at 31 microsatellites for dam, sire, and offspring in each of two families used in testing Mendelian segregation and independent assortment

<u>Family 1</u>	<u>Soc 138</u>	<u>Soc 140</u>	<u>Soc 156</u>	<u>Soc 201</u>	<u>Soc 206</u>	<u>Soc 243</u>
Dam	91/103	137/137	184/181	232/236	253/257	92/92
Sire	91/91	137/145	184/181	234/234	253/257	89/89
1	91/103	137/137	181/184	234/236	253/257	89/92
2	91/103	137/137	181/184	232/234	253/257	89/92
3	91/103	137/145	181/181	234/236	257/257	89/92
4	91/91	137/145	184/184	232/232	257/257	89/92
5	91/103	137/145	181/181	232/234	257/257	89/92
6	91/103	137/137	181/184	232/232	257/257	89/92
7	91/103	137/137	181/181	234/236	257/257	89/92
8	91/91	137/137	181/184	236/236	257/257	89/92
9	91/91	137/137	181/184	234/236	253/257	89/92
10	91/103	137/145	181/181	232/232	253/253	----
11	91/103	137/145	181/181	232/234	253/253	89/92
12	91/91	137/137	184/184	----	253/257	89/92
13	91/103	137/145	181/181	234/236	253/257	89/92
14	91/103	137/145	181/184	232/234	253/253	89/92
15	91/91	137/137	181/184	236/236	253/257	89/92
16	91/103	137/137	181/181	232/232	253/257	89/92
17	91/103	137/145	181/184	234/236	253/257	89/92
18	91/103	137/145	184/184	232/234	253/257	89/92
19	91/103	137/145	181/181	234/236	253/257	89/92
20	91/91	137/137	184/184	232/232	257/257	89/92
21	91/103	137/137	181/181	236/236	253/257	89/92
22	91/103	137/145	181/184	234/236	253/257	89/92
23	----	----	----	----	----	----
24	91/91	137/137	184/184	----	253/253	89/92
25	91/91	137/145	184/184	232/232	257/257	89/92
26	91/103	137/137	181/184	232/232	257/257	89/92
27	91/103	137/137	181/184	232/234	253/257	89/92
28	91/91	137/145	181/184	232/234	253/253	----
29	91/91	137/137	184/184	232/232	253/253	89/92
30	91/91	137/145	184/184	232/234	----	89/92
31	91/103	137/145	181/181	232/234	----	89/92
32	91/103	137/145	181/181	----	253/253	89/92
33	91/91	137/145	184/184	234/236	253/253	89/92

34	91/103	137/137	181/181	236/236	257/257	89/92
35	91/91	137/137	181/184	232/232	253/257	89/92
36	91/103	137/137	181/184	232/232	257/257	89/92
37	91/91	137/145	184/184	236/236	257/257	89/92
38	91/91	137/137	184/184	232/234	253/257	89/92
39	91/91	137/137	181/184	232/234	257/257	89/92
40	91/103	137/145	181/184	234/236	253/257	89/92
41	91/103	137/137	181/181	232/234	----	89/92
42	91/103	137/137	181/181	236/236	----	89/92
43	91/103	137/145	181/181	234/236	----	89/92
44	91/91	137/145	184/184	232/234	----	89/92
45	91/103	137/137	181/181	234/236	----	89/92
46	91/103	137/145	181/184	232/232	257/257	89/92
47	91/103	----	181/181	236/236	253/253	----
48	91/103	----	181/184	234/236	253/253	----
49	91/103	137/137	181/181	232/234	253/257	89/92
50	91/91	137/137	181/184	232/234	253/253	89/92
51	91/103	137/145	181/181	232/234	253/257	89/92
52	91/91	137/145	181/184	232/234	253/253	89/92
53	91/103	137/145	181/184	232/234	257/257	89/92
54	91/91	137/145	181/184	234/236	----	89/92
55	91/103	137/137	181/181	234/236	----	89/92
56	91/91	137/137	184/184	236/236	253/257	89/92
57	91/91	137/137	181/184	234/236	257/257	89/92
58	91/103	137/137	181/181	232/234	253/257	89/92
59	91/103	137/137	181/181	236/236	253/257	89/92
60	91/103	137/137	181/184	232/234	253/257	89/92
61	91/91	137/145	184/184	232/232	253/257	89/92
62	91/103	137/137	181/181	234/236	253/257	89/92
63	91/103	137/137	181/181	232/234	253/257	89/92
64	91/103	137/137	181/181	236/236	257/257	89/92
65	91/103	137/137	181/181	236/236	253/253	89/92
66	91/103	137/145	181/184	232/232	257/257	89/92
67	91/103	137/137	181/181	232/232	257/257	89/92
68	91/103	137/137	181/184	232/232	253/257	89/92
69	91/103	137/137	181/184	232/234	253/257	89/92
70	91/91	137/137	184/184	236/236	253/257	89/92
71	91/91	137/137	----	236/236	----	89/92
72	91/103	137/137	181/181	232/232	253/257	89/92
73	91/103	137/145	181/181	234/236	257/257	89/92

74	91/103	137/137	181/184	236/236	253/257	89/92
75	91/91	137/137	181/181	234/236	253/253	89/92
76	91/91	137/145	181/184	234/236	253/253	89/92
77	91/91	137/137	181/184	----	253/253	89/92
78	91/103	137/137	181/184	234/236	257/257	89/92
79	91/103	137/137	181/184	234/236	257/257	89/92
80	91/91	137/137	181/184	232/234	253/257	89/92
81	91/91	137/145	181/184	232/234	257/257	89/92
82	91/91	137/145	181/184	234/236	253/253	89/92
83	91/103	137/145	181/184	232/234	253/257	89/92
84	91/103	137/145	181/184	232/234	257/257	89/92
85	91/91	137/137	181/184	236/236	253/253	89/92
86	91/91	137/145	181/184	232/232	257/257	89/92
87	91/91	137/137	181/184	236/236	253/257	89/92
88	91/91	137/137	181/184	232/234	253/257	89/92
89	91/103	137/145	181/181	232/234	253/257	89/92
90	91/91	137/145	184/184	234/236	253/253	89/92
91	91/103	137/137	181/181	232/232	253/257	89/92
92	91/103	137/142	181/181	232/234	253/253	89/95
93	91/103	137/145	181/181	234/236	253/253	89/92
94	91/91	137/145	181/184	232/234	253/257	89/92
95	91/91	137/145	184/184	232/232	253/253	89/92
96	91/91	137/137	181/184	232/234	253/253	89/92
97	91/103	137/145	181/181	236/236	253/257	89/92
98	91/103	137/137	181/184	232/232	253/253	89/92
99	91/103	137/145	181/184	232/232	257/257	89/92
100	91/103	137/137	181/184	232/232	253/257	89/92
101	91/91	137/145	184/184	234/236	253/257	89/92
102	91/91	137/137	184/184	234/236	257/257	89/92
103	91/91	137/137	184/184	----	253/257	89/92
104	91/103	137/137	181/181	232/234	253/257	89/92
105	91/103	137/137	181/184	234/236	253/257	89/92
106	91/91	137/137	184/184	234/236	253/257	89/92
107	91/91	137/137	181/184	232/234	253/253	89/92
108	91/103	137/145	181/184	232/234	253/257	89/92
109	91/103	137/145	181/184	234/236	257/257	89/92
110	91/103	137/137	181/181	236/236	253/257	89/92
111	91/91	137/145	184/184	232/232	257/257	89/92
112	91/91	137/145	184/184	236/236	253/253	89/92
113	91/103	137/145	181/181	234/236	253/257	89/92

114	91/91	137/137	181/181	232/232	253/253	89/92
115	91/103	137/145	181/184	236/236	253/257	89/92
116	91/103	137/137	181/181	----	257/257	89/92
117	91/91	137/137	181/184	234/236	253/257	89/92
118	91/91	137/137	181/181	236/236	253/253	89/92
119	91/103	137/137	181/184	236/236	253/253	89/92
120	91/103	137/145	181/181	236/236	253/253	89/92
121	----	137/145	----	----	----	89/92
122	91/91	137/137	181/184	----	253/257	89/92
123	91/91	137/137	184/184	232/232	253/257	89/92
124	91/103	137/145	181/181	----	253/253	89/92
125	91/103	137/145	184/184	236/236	253/257	89/92
126	91/103	137/145	181/184	----	253/257	89/92
<u>Family 2</u>	<u>Soc 138</u>	<u>Soc 140</u>	<u>Soc 156</u>	<u>Soc 201</u>	<u>Soc 206</u>	<u>Soc 243</u>
Dam	99/99	137/145	181/181	232/234	257/257	92/95
Sire	95/103	137/145	184/181	232/237	253/257	89/92
1	95/99	137/145	181/184	232/232	253/257	92/92
2	99/103	137/137	181/181	232/234	253/257	92/92
3	95/99	145/145	181/184	232/234	257/257	92/95
4	99/103	137/145	181/181	232/237	257/257	92/92
5	99/103	137/145	181/184	232/234	253/257	92/92
6	95/99	145/145	181/184	234/237	253/257	92/95
7	99/103	137/137	181/181	232/232	253/257	92/95
8	99/103	145/145	181/181	234/237	257/257	92/92
9	99/103	145/145	181/181	234/237	257/257	89/95
10	99/103	137/145	181/181	234/237	253/257	89/92
11	----	----	----	----		89/92
12	99/103	145/145	181/184	234/237	257/257	92/92
13	99/103	137/145	181/181	232/237	257/257	89/95
14	95/99	137/145	181/181	232/234	257/257	89/92
15	95/99	145/145	181/181	234/237	253/257	92/92
16	95/99	137/145	181/181	234/237	257/257	89/93
17	95/99	137/137	181/181	232/234	253/257	89/95
18	95/99	145/145	181/181	232/232	257/257	93/95
19	99/103	137/145	181/184	232/237	253/257	89/95
20	99/103	137/145	181/184	232/232	257/257	92/92
21	95/99	137/137	181/184	232/234	257/257	89/92
22	95/99	137/137	181/181	232/234	257/257	92/95
23	99/103	145/145	181/184	232/237	253/257	92/92
24	95/99	145/145	181/181	232/237	257/257	92/94



25	95/99	145/145	181/181	232/237	253/257	92/92
26	95/99	137/137	181/181	232/234	257/257	89/95
27	----	137/137	----	232/234	----	89/95
28	99/103	145/145	181/184	232/237	253/257	92/92
29	99/103	137/145	181/181	232/232	253/257	92/92
30	95/99	145/145	181/184	234/237	253/257	92/92
31	99/103	145/145	181/181	234/237	253/257	92/95
32	95/99	137/145	181/184	232/234	253/257	89/92
33	99/103	137/137	181/184	232/232	253/257	92/95
34	95/99	137/145	181/181	232/232	257/257	92/92
35	99/103	137/145	181/181	234/237	257/257	89/95
36	95/99	145/145	181/181	232/234	257/257	92/95
37	95/99	137/145	181/184	232/234	253/257	89/92
38	99/103	137/145	181/181	232/234	253/257	89/92
39	99/103	137/145	181/181	232/234	253/257	89/95
40	99/103	137/145	181/181	232/237	257/257	89/95
41	99/103	137/145	181/181	232/237	257/257	89/92
42	99/103	137/145	181/184	232/234	253/257	92/95
43	95/99	145/145	181/181	232/237	253/257	89/95
44	95/99	145/145	181/184	232/237	257/257	92/95
45	95/99	145/145	181/181	232/232	253/257	89/92
46	95/99	145/145	181/181	232/232	257/257	92/92
47	95/99	145/145	181/181	232/232	253/257	89/92
48	95/99	137/145	181/184	232/232	253/257	89/92
49	95/99	137/145	181/184	232/237	257/257	89/92
50	95/99	137/137	181/181	----	253/257	----
51	99/103	137/145	181/181	234/237	257/257	92/92
52	95/99	137/145	181/181	232/232	257/257	92/95
53	99/103	137/145	181/184	234/237	253/257	89/95
54	95/99	137/145	181/184	232/237	253/257	92/92
55	99/103	137/145	181/181	234/237	253/257	89/92
56	95/99	145/145	181/181	232/232	257/257	92/92
57	95/99	137/137	181/181	234/237	257/257	89/92
58	99/103	137/137	181/184	232/237	253/257	89/95
59	95/99	137/145	181/181	232/232	253/257	89/92
60	99/103	137/137	181/181	232/237	257/257	92/92
61	99/103	137/145	181/181	232/232	253/257	92/95
62	95/99	137/137	181/181	232/237	253/257	89/92
63	99/103	137/145	181/181	232/237	257/257	92/92
64	95/99	145/145	181/184	234/237	253/257	92/92

65	99/103	137/145	181/184	234/237	257/257	92/95
66	99/103	145/145	181/184	232/232	253/257	92/92
67	99/103	137/145	181/184	232/237	257/257	92/95
68	95/99	137/145	181/181	232/234	257/257	92/95
69	95/99	137/137	181/181	232/237	253/257	89/92
70	99/103	137/145	181/184	232/232	257/257	89/92
71	99/103	145/145	181/184	234/237	257/257	92/92
72	99/103	137/137	181/181	232/237	253/257	89/95
73	99/103	137/145	181/184	232/237	253/257	89/92
74	99/103	137/137	181/184	232/232	257/257	92/95
75	99/103	145/145	181/184	232/232	257/257	89/92
76	95/99	137/137	181/184	232/237	253/257	92/92
77	99/103	137/137	181/184	232/232	257/257	92/95
78	99/103	137/145	181/184	234/237	253/257	89/92
79	99/103	145/145	181/184	232/237	257/257	89/95
80	99/103	137/137	181/181	232/234	257/257	89/95
81	99/103	137/145	181/181	232/234	257/257	92/95
82	95/99	137/145	181/184	232/232	253/257	89/92
83	99/103	137/145	181/181	232/232	253/257	92/95
84	99/103	137/145	181/181	232/234	257/257	92/92
85	99/103	137/137	181/181	232/232	257/257	92/92
86	99/103	137/145	181/181	232/232	253/257	92/92
87	99/103	137/145	181/181	232/232	253/257	92/95
88	95/99	137/137	181/181	232/234	253/257	89/95
89	99/103	137/145	181/181	232/234	257/257	92/92
90	95/99	137/145	181/181	232/234	253/257	92/95
91	95/99	137/145	181/181	232/237	253/257	89/92
92	95/99	145/145	181/181	232/234	257/257	92/92
93	95/99	145/145	181/181	232/237	253/257	89/95
94	95/99	137/137	181/181	234/237	253/257	89/92
95	95/99	137/145	181/181	232/234	253/257	92/95
96	99/103	137/137	181/184	234/237	253/257	89/95
97	99/103	137/145	181/184	232/234	257/257	92/92
98	95/99	145/145	181/184	232/234	253/257	92/95
99	99/103	137/137	181/181	234/237	253/257	89/95
100	95/99	137/145	181/181	232/232	253/257	89/92
101	99/103	145/145	181/184	234/237	253/257	92/95
102	99/103	137/137	181/184	232/232	253/257	92/95
103	95/99	137/145	181/184	232/237	253/257	89/95
104	99/103	137/145	181/184	232/232	253/257	92/92

105	----	137/145	181/184	232/232	253/257	92/92
106	95/99	137/137	181/184	232/234	257/257	92/95
107	95/99	137/137	181/184	232/234	257/257	92/95
108	99/103	137/137	181/184	234/237	257/257	92/92
109	95/99	145/145	181/184	234/237	253/257	89/92
110	99/103	137/137	181/184	232/232	253/257	89/92
111	99/103	145/145	181/181	232/237	253/257	92/95
112	99/103	137/137	181/184	232/232	257/257	92/92
113	99/103	137/145	181/181	232/234	257/257	89/92
114	95/99	137/145	181/184	232/232	253/257	89/92
115	95/99	137/145	181/184	232/234	253/257	89/92
116	95/99	137/137	181/184	232/234	257/257	89/92
117	95/99	137/145	181/184	232/232	257/257	89/95
118	95/99	137/145	181/181	232/237	253/257	89/95
119	95/99	137/137	181/181	232/237	257/257	89/95
120	99/103	137/137	181/181	232/237	253/257	89/95
121	95/99	137/145	181/181	232/237	253/257	92/92
122	95/99	137/145	181/184	232/234	257/257	89/92
123	----	137/145	181/184	----	----	89/95

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### APPENDIX 12c

Genotypes at 31 microsatellites for dam, sire, and offspring in each of two families used in testing Mendelian segregation and independent assortment

<u>Family 1</u>	<u>Soc 400</u>	<u>Soc 401</u>	<u>Soc 402</u>	<u>Soc 404</u>	<u>Soc 407</u>	<u>Soc 410</u>
Dam	250/250	176/176	144/148	160/194	142/158	318/318
Sire	256/266	178/200	138/148	174/212	146/148	324/330
1	250/266	176/178	138/148	174/194	142/146	318/330
2	250/266	178/200	144/148	194/212	146/158	318/330
3	----	200/200	148/148	----	146/158	318/324
4	250/266	176/200	144/148	160/174	146/158	318/330
5	250/266	176/200	144/148	194/212	142/148	318/330
6	250/266	176/200	144/148	160/174	146/158	318/324
7	250/256	176/200	144/148	174/194	142/148	318/324
8	250/256	176/200	144/148	194/212	148/158	318/324
9	250/256	178/178	138/148	174/194	148/158	318/330
10	250/256	176/178	138/144	160/174	142/148	318/330
11	250/256	176/200	144/148	174/194	142/148	318/324
12	250/266	176/178	138/144	160/174	142/146	318/324
13	250/266	176/200	144/148	160/212	148/158	318/330
14	250/266	200/200	148/148	174/194	142/146	318/330
15	250/256	176/178	138/144	160/212	148/158	318/330
16	250/266	178/178	138/148	160/212	146/158	318/324
17	250/256	200/200	148/148	160/212	142/148	318/330
18	250/256	176/178	138/144	174/194	148/158	318/324
19	250/266	178/178	138/148	174/194	146/158	318/324
20	250/266	176/178	138/144	194/212	146/158	318/324
21	250/266	178/178	138/144	194/212	142/148	318/324
22	250/266	178/178	138/148	160/174	142/146	318/324
23	----	----	----	----	----	----
24	250/256	176/178	138/144	194/212	148/158	318/324
25	250/266	200/200	148/148	194/212	142/146	318/324
26	250/256	176/178	138/144	174/194	142/146	318/330
27	250/256	176/178	138/144	174/194	142/148	318/324
28	250/266	200/200	148/148	160/212	146/158	318/324
29	250/256	178/178	138/148	174/194	148/158	318/324
30	250/266	200/200	148/148	194/212	142/146	318/330
31	250/256	176/200	144/148	174/194	148/158	318/330
32	250/266	176/178	138/144	160/174	146/158	318/324
33	250/266	176/178	138/144	194/212	146/158	318/330

34	250/266	200/200	148/148	194/212	146/158	318/324
35	250/256	176/178	138/144	174/194	142/148	318/324
36	250/256	176/178	138/144	160/174	142/148	318/324
37	250/266	176/178	138/144	194/212	146/158	318/330
38	250/266	176/178	138/144	174/194	142/146	318/324
39	250/256	176/200	144/148	160/174	142/148	318/324
40	250/266	200/200	148/148	160/174	142/146	318/324
41	250/256	178/178	138/148	160/212	142/148	318/324
42	250/266	176/178	138/144	160/212	142/148	318/324
43	250/266	178/178	138/148	160/212	142/148	318/324
44	250/266	200/200	148/148	160/212	146/158	318/330
45	250/256	176/200	144/148	174/194	142/148	318/324
46	250/266	200/200	148/148	194/212	142/146	318/324
47	250/256	176/200	144/148	174/194	148/158	318/330
48	250/256	200/200	148/148	160/174	142/148	318/330
49	250/256	176/178	138/144	160/174	142/148	318/330
50	250/256	200/200	148/148	160/212	148/158	318/324
51	250/256	176/178	138/144	194/212	148/158	318/324
52	250/256	200/200	148/148	160/174	142/146	318/324
53	250/256	200/200	148/148	194/212	148/158	318/324
54	250/266	200/200	148/148	160/212	146/158	318/330
55	250/266	200/200	148/148	194/212	142/146	318/330
56	250/266	176/200	144/148	194/212	146/158	318/324
57	250/266	176/178	138/144	160/212	142/146	318/330
58	250/256	200/200	148/148	194/212	148/158	318/324
59	250/266	178/178	138/148	194/212	142/146	318/324
60	250/266	200/200	148/148	160/212	142/146	318/324
61	250/256	178/178	138/148	174/194	148/158	318/330
62	250/256	178/178	138/148	160/174	142/148	318/324
63	250/256	178/178	138/148	160/174	142/148	318/330
64	250/266	200/200	148/148	194/212	142/146	318/330
65	250/256	200/200	148/148	160/212	142/148	318/324
66	250/256	176/178	138/144	194/212	142/148	318/324
67	250/266	176/200	144/148	160/212	142/146	318/330
68	250/256	178/178	138/148	160/174	142/148	318/330
69	250/256	176/200	144/148	174/194	142/146	318/330
70	250/266	176/200	144/148	160/212	146/158	318/330
71	250/256	200/200	148/148	160/212	142/148	----
72	250/266	200/200	148/148	174/194	142/146	318/324
73	250/266	176/200	144/148	194/212	146/158	318/324

74	250/266	178/178	138/148	194/212	142/146	318/330
75	250/256	200/200	148/148	194/212	148/158	318/324
76	250/266	178/178	138/148	194/212	146/158	318/330
77	250/266	176/200	144/148	174/194	146/158	318/324
78	250/256	176/178	138/144	194/212	148/158	318/324
79	250/266	200/200	148/148	160/174	146/158	318/324
80	250/256	176/200	144/148	174/194	142/148	318/324
81	250/256	178/178	138/148	194/212	142/148	318/324
82	250/266	178/178	138/148	160/174	142/148	318/324
83	250/256	176/200	144/148	174/194	142/148	318/330
84	250/266	200/200	148/148	194/212	146/158	318/330
85	250/256	178/178	138/148	160/212	148/158	318/330
86	250/266	178/178	138/148	160/174	146/158	318/330
87	250/256	176/200	144/148	160/212	142/148	318/324
88	250/266	178/178	138/148	174/194	142/146	318/330
89	250/266	176/178	138/144	160/174	142/146	318/330
90	250/266	176/178	144/148	160/174	146/158	318/330
91	250/266	176/200	144/148	174/194	142/146	318/324
92	----	180/180	146/152	170/204	152/154	318/326
93	250/266	178/178	138/148	160/212	146/158	318/324
94	250/256	176/178	138/144	160/174	142/146	318/324
95	250/256	176/200	144/148	160/174	148/158	318/330
96	250/256	200/200	148/148	194/212	146/158	318/324
97	250/266	176/178	144/148	160/212	146/158	318/324
98	250/256	176/200	144/148	174/194	142/148	318/324
99	250/266	200/200	148/148	174/194	142/146	318/324
100	250/256	176/200	144/148	174/194	142/148	318/324
101	250/256	178/178	138/148	174/194	142/148	318/330
102	250/266	176/178	138/144	194/212	146/158	318/330
103	250/256	178/178	138/148	174/194	148/158	318/324
104	250/266	176/200	144/148	160/212	142/146	318/324
105	250/256	176/206	144/148	160/212	148/158	318/324
106	250/266	176/178	138/144	160/212	146/158	318/324
107	250/256	----	148/148	160/212	148/158	318/330
108	250/256	176/178	138/144	160/212	142/148	318/330
109	250/266	176/200	144/148	160/212	142/146	318/330
110	250/266	178/178	138/148	194/212	142/146	318/330
111	250/256	178/178	138/148	160/212	142/148	318/324
112	250/266	176/200	144/148	160/174	146/158	318/330
113	----	200/200	148/148	----	142/146	318/324

114	250/256	176/178	138/144	194/212	142/148	318/324
115	250/266	176/178	138/144	174/194	142/146	318/324
116	----	----	144/148	160/174	142/146	----
117	250/256	178/178	138/148	194/212	148/158	318/330
118	250/266	200/200	138/148	160/174	142/146	318/324
119	250/266	176/178	138/144	160/174	142/146	318/324
120	250/266	178/178	138/148	160/174	142/146	318/324
121	----	----	----	----	142/146	----
122	250/266	178/178	138/148	174/194	146/158	318/324
123	250/256	200/200	148/148	160/174	142/148	318/324
124	250/266	176/178	138/144	160/212	146/158	318/324
125	250/256	178/178	138/148	174/194	142/148	318/324
126	250/266	178/178	138/148	174/194	146/158	318/324
<u>Family 2</u>	<u>Soc 400</u>	<u>Soc 401</u>	<u>Soc 402</u>	<u>Soc 404</u>	<u>Soc 407</u>	<u>Soc 410</u>
Dam	250/256	174/176	138/140	160/200	144/152	320/322
Sire	250/258	180/188	148/148	160/170	148/154	318/320
1	256/258	174/180	140/148	160/200	148/152	318/322
2	256/258	176/180	140/148	170/200	144/154	320/322
3	256/258	174/188	138/148	160/170	152/154	320/322
4	250/258	176/188	138/148	170/200	148/152	318/322
5	250/250	176/188	138/148	160/160	144/148	320/320
6	250/258	176/188	138/148	160/200	152/154	318/322
7	250/258	174/180	140/148	160/160	144/154	318/322
8	250/256	176/188	138/148	170/200	144/148	320/322
9	250/250	174/180	138/148	160/200	144/148	320/320
10	256/258	174/188	138/148	160/200	152/154	320/322
11	----	176/180	138/148	160/160	----	----
12	256/258	174/180	140/148	160/160	144/148	318/322
13	250/258	176/188	138/148	160/200	144/154	320/322
14	250/258	174/180	140/148	170/200	148/152	320/320
15	250/258	174/180	140/148	160/170	152/154	320/320
16	256/258	174/188	138/148	170/200	152/154	318/320
17	250/258	176/188	138/148	160/170	144/154	318/320
18	256/258	174/188	138/148	160/170	144/154	318/320
19	256/258	176/180	140/148	160/170	152/154	320/320
20	250/250	174/180	140/148	170/200	152/154	320/322
21	256/258	176/188	138/148	160/170	144/154	320/320
22	256/258	176/180	140/148	160/200	152/154	318/322
23	250/256	176/180	140/148	160/170	144/148	320/322
24	250/258	174/188	138/148	170/200	144/154	320/320

25	256/258	174/188	138/148	160/200	144/154	320/322
26	250/258	176/180	138/148	170/200	152/154	318/322
27	----	174/180	140/148	----	----	----
28	250/250	174/180	140/148	160/200	144/148	318/322
29	250/256	174/188	138/148	170/200	144/148	320/320
30	250/250	174/188	138/148	160/200	144/148	318/320
31	250/258	174/188	138/148	160/170	144/154	318/320
32	256/258	176/180	140/148	160/200	144/154	318/322
33	250/256	176/180	140/148	170/200	148/152	318/320
34	250/250	174/180	140/148	160/170	144/148	318/322
35	250/250	176/180	140/148	160/160	152/154	320/322
36	250/258	174/180	140/148	160/160	144/154	320/322
37	250/250	174/180	140/148	160/170	148/152	318/320
38	250/258	174/180	140/148	170/200	144/154	318/320
39	250/256	174/180	140/148	160/170	144/148	318/322
40	250/256	174/188	138/148	170/200	148/152	318/320
41	256/258	176/188	138/148	160/170	152/154	318/322
42	250/258	174/188	138/148	170/200	144/154	320/320
43	256/258	174/188	138/148	160/200	152/154	318/322
44	250/256	176/180	140/148	170/200	148/152	320/320
45	250/258	174/180	140/148	160/200	144/154	318/320
46	250/258	174/188	138/148	160/160	144/154	320/320
47	250/256	176/180	140/148	160/160	144/148	320/322
48	250/256	174/188	138/148	160/170	144/148	320/322
49	250/250	174/188	138/148	160/160	152/154	318/322
50	250/250	176/188	138/148	160/200	144/148	320/322
51	250/258	176/180	140/148	160/160	152/154	318/322
52	256/258	176/188	138/148	170/200	144/154	318/320
53	256/258	174/180	140/148	170/200	152/154	320/322
54	250/258	174/180	140/148	160/200	152/154	318/322
55	250/256	174/188	138/148	160/170	144/154	318/322
56	256/258	174/180	140/148	160/160	148/152	320/320
57	256/258	176/180	140/148	170/200	144/154	320/322
58	250/250	174/188	138/148	160/200	148/152	318/322
59	250/258	176/188	138/148	160/170	148/152	318/322
60	256/258	176/188	138/148	160/200	152/154	318/322
61	250/256	174/180	138/148	160/200	148/152	318/320
62	256/258	174/180	138/148	160/170	152/154	318/320
63	250/256	174/188	138/148	160/160	144/148	318/320
64	250/258	174/188	140/148	160/160	144/154	320/322



65	250/258	176/188	138/148	160/200	152/154	320/320
66	256/258	174/188	138/148	170/200	144/154	320/322
67	250/258	174/180	140/148	160/200	152/154	320/320
68	250/258	174/188	138/148	160/200	144/154	320/320
69	250/256	174/180	140/148	160/170	144/148	320/322
70	256/258	174/188	138/148	170/200	152/154	320/322
71	256/258	174/180	140/148	160/170	144/154	318/322
72	250/256	176/180	138/148	160/200	144/148	318/322
73	250/250	174/188	138/148	160/170	144/148	318/322
74	250/258	174/188	138/148	160/170	144/154	318/322
75	256/258	174/180	140/148	160/170	152/154	320/322
76	256/258	174/180	140/148	170/200	152/154	318/320
77	250/258	176/180	140/148	160/160	152/154	320/320
78	250/250	174/188	138/148	160/200	148/152	320/320
79	250/250	174/180	140/148	160/200	144/148	320/320
80	250/256	176/188	138/148	160/200	144/148	318/320
81	250/258	176/188	138/148	160/200	152/154	320/320
82	250/258	176/180	140/148	160/200	152/154	320/322
83	250/256	176/180	140/148	160/160	144/148	320/320
84	250/256	176/188	138/148	160/200	152/154	320/320
85	250/258	176/180	140/148	160/160	144/154	320/322
86	250/258	174/180	140/148	170/200	144/154	318/322
87	256/258	174/180	140/148	160/170	144/154	318/322
88	256/258	176/180	140/148	160/160	144/154	320/322
89	250/258	174/180	140/148	160/160	144/154	318/322
90	256/258	174/188	138/148	170/200	152/154	318/322
91	256/258	174/188	138/148	160/200	144/154	318/322
92	250/258	176/180	140/148	160/170	144/148	318/320
93	256/258	174/180	140/148	170/200	152/154	318/320
94	256/258	176/180	140/148	160/200	144/154	320/320
95	256/258	176/180	140/148	160/200	152/154	320/320
96	250/258	176/180	140/148	160/170	144/154	320/322
97	250/256	174/188	138/148	160/200	144/148	320/320
98	250/256	174/188	138/148	170/200	144/148	320/322
99	250/258	174/188	138/148	160/200	152/154	320/320
100	250/250	176/188	138/148	160/200	144/148	318/322
101	250/258	176/188	138/148	160/170	144/154	320/320
102	250/250	176/188	138/148	160/200	144/148	320/322
103	250/258	174/188	138/148	170/200	152/154	320/322
104	250/258	174/188	140/148	160/160	144/154	320/320

105	250/256	174/180	138/148	170/200	148/152	318/322
106	250/256	174/188	138/148	170/200	144/148	318/322
107	250/250	174/188	140/148	160/160	144/148	318/322
108	250/256	176/180	140/148	170/200	148/152	320/320
109	250/256	176/180	140/148	170/200	148/152	320/322
110	250/256	174/180	138/148	170/200	144/148	320/322
111	250/258	174/180	138/148	170/200	148/152	320/320
112	250/256	174/188	140/148	160/200	144/148	320/320
113	256/258	174/188	140/148	160/160	152/154	320/320
114	250/256	176/180	140/148	160/170	148/152	320/320
115	250/250	176/180	138/148	160/200	144/148	320/320
116	250/258	176/180	138/148	160/160	144/154	320/322
117	250/258	174/188	138/148	160/200	152/154	320/320
118	256/258	176/188	138/148	170/200	144/154	320/320
119	250/258	174/188	138/148	170/200	144/154	318/322
120	250/258	174/188	140/148	160/170	144/154	318/322
121	250/258	176/188	138/148	170/200	152/154	318/322
122	250/258	174/180	138/148	170/200	144/154	320/320
123	250/258	176/180	140/148	160/160	----	----

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### APPENDIX 12d

Genotypes at 31 microsatellites for dam, sire, and offspring in each of two families used in testing Mendelian segregation and independent assortment

<u>Family 1</u>	<u>Soc 412</u>	<u>Soc 415</u>	<u>Soc 416</u>	<u>Soc 417</u>	<u>Soc 419</u>	<u>Soc 423</u>
Dam	148/166	191/195	153/163	92/106	246/252	179/179
Sire	152/156	217/217	159/169	94/94	248/254	195/207
1	148/152	227/233	153/159	92/94	252/254	179/195
2	156/166	217/227	153/169	92/94	252/254	179/207
3	148/152	----	153/159	92/94	246/254	179/195
4	148/156	195/217	163/169	94/106	246/254	179/195
5	148/156	195/217	163/169	94/106	246/254	179/207
6	148/156	217/227	153/169	92/94	246/254	179/195
7	148/152	217/227	153/169	92/94	252/254	179/207
8	148/156	227/233	153/159	92/94	246/254	179/195
9	156/166	217/227	153/169	92/94	252/254	179/195
10	156/166	227/233	153/159	92/94	248/252	179/195
11	148/156	227/233	153/159	92/94	246/248	179/207
12	152/166	195/217	163/169	94/106	248/252	179/207
13	148/152	195/233	159/163	94/106	252/254	179/195
14	148/152	195/217	163/169	94/106	246/248	179/207
15	148/152	227/233	153/159	92/94	246/254	179/207
16	148/156	195/233	159/163	94/106	246/254	179/207
17	148/156	195/217	163/169	94/106	246/254	179/195
18	148/156	195/217	163/169	94/106	248/252	179/195
19	148/156	195/217	163/169	94/106	252/254	179/195
20	156/166	195/233	159/163	94/106	246/254	179/207
21	152/166	195/217	163/169	94/106	252/254	179/195
22	148/152	227/233	153/159	92/94	248/252	179/195
23	----	----	----	----	----	----
24	148/152	195/233	159/163	94/106	248/252	179/207
25	152/166	195/233	159/163	94/106	246/254	179/207
26	148/152	195/233	159/163	94/106	246/254	179/207
27	156/166	227/233	153/159	92/94	252/254	179/207
28	148/156	195/217	163/169	94/106	252/254	179/207
29	156/166	195/217	163/169	94/106	248/252	179/207
30	156/166	195/233	159/163	94/106	252/254	179/195
31	148/156	217/227	153/169	92/94	248/252	179/207
32	148/152	217/227	153/169	92/94	248/252	179/207
33	148/156	195/233	159/163	94/106	248/252	179/195

34	----	195/233	----	94/106	246/254	179/195
35	156/166	217/227	153/169	92/94	248/252	179/207
36	148/156	227/233	153/159	92/94	246/254	179/207
37	152/166	217/227	153/169	92/94	252/254	179/207
38	152/166	195/233	159/163	94/106	246/254	179/195
39	148/156	217/227	153/169	92/94	246/254	179/207
40	148/152	195/217	163/169	94/106	252/254	179/195
41	148/152	227/233	153/159	92/94	248/252	179/195
42	156/166	217/227	153/169	92/94	246/254	179/207
43	156/166	195/233	159/163	94/106	248/252	179/207
44	148/156	195/217	163/169	94/106	246/254	179/195
45	156/166	227/233	153/159	92/94	252/254	179/207
46	156/166	217/227	153/169	92/94	246/248	179/207
47	152/166	217/227	153/169	92/94	----	179/207
48	148/152	195/217	163/169	94/106	----	179/207
49	148/156	195/233	159/163	94/106	252/254	179/195
50	152/166	227/233	153/159	92/94	246/248	179/195
51	148/156	195/217	163/169	94/106	246/248	179/207
52	156/166	195/217	163/169	94/106	246/248	179/207
53	148/156	195/233	159/163	94/106	246/254	179/195
54	156/166	195/233	159/163	94/106	252/254	179/207
55	152/166	227/233	153/159	92/94	252/254	179/207
56	152/166	227/233	153/159	92/94	252/254	179/195
57	148/152	227/233	153/159	92/94	246/254	179/207
58	156/166	195/233	159/163	94/106	252/254	179/207
59	156/166	195/233	159/163	94/106	252/254	179/195
60	148/156	195/217	163/169	94/106	252/254	179/195
61	156/166	195/217	163/169	94/106	248/252	179/195
62	148/152	195/233	163/167	94/106	248/252	179/195
63	148/152	195/217	163/169	94/106	248/252	179/207
64	148/156	217/227	153/169	92/94	246/254	179/195
65	152/166	195/217	163/169	94/106	248/252	179/207
66	148/156	195/217	163/169	94/106	252/254	179/207
67	152/166	217/227	153/169	92/94	246/254	179/195
68	148/152	217/227	153/169	92/94	252/254	179/195
69	148/152	195/217	163/169	94/106	246/248	179/195
70	148/152	227/233	153/159	92/94	246/248	179/195
71	148/156	195/233	159/163	94/106	248/252	179/195
72	148/156	217/227	153/169	92/94	248/252	179/195
73	148/152	227/233	153/159	92/94	246/254	179/207

74	148/152	195/233	159/163	94/106	246/254	179/207
75	148/152	227/233	153/159	92/94	246/248	179/195
76	148/156	227/233	153/159	92/94	248/252	179/207
77	148/152	195/233	159/163	94/106	248/252	179/195
78	148/152	217/227	153/169	92/94	246/254	179/207
79	148/152	195/217	163/169	94/106	248/252	179/207
80	156/166	195/217	163/169	94/106	252/254	179/195
81	148/166	217/227	153/169	92/94	246/254	179/195
82	148/152	195/217	163/169	94/106	248/252	179/207
83	148/156	195/217	163/169	94/106	248/252	179/195
84	148/156	217/227	153/169	92/94	246/254	179/207
85	148/152	217/227	153/169	92/94	248/252	179/195
86	148/152	227/233	153/159	92/94	246/254	179/195
87	156/166	227/233	153/159	92/94	248/252	179/207
88	148/156	217/227	153/169	92/94	252/254	179/207
89	152/166	227/233	153/159	92/94	248/252	179/207
90	148/156	227/233	153/159	92/94	248/252	179/207
91	----	195/217	----	94/106	252/254	179/195
92	----	----	153/169	92/94	246/252	----
93	148/152	217/227	153/169	92/94	248/252	179/195
94	148/152	195/217	163/169	94/106	248/252	179/195
95	152/166	217/227	153/169	92/94	248/252	179/195
96	152/166	195/233	159/163	94/106	248/252	179/195
97	152/166	195/233	159/163	94/106	252/254	179/195
98	156/166	217/227	153/169	92/94	246/248	179/195
99	156/166	195/217	163/169	94/106	246/254	179/207
100	156/166	217/227	153/169	92/94	246/248	179/195
101	148/152	227/233	153/159	92/94	246/248	179/195
102	148/156	195/217	163/169	94/106	246/254	179/207
103	----	----	----	92/94	246/254	----
104	148/156	195/233	159/163	94/106	252/254	179/195
105	148/152	195/233	159/163	94/106	246/254	179/207
106	148/152	217/227	153/169	92/94	248/252	179/195
107	148/156	195/233	159/163	94/106	252/254	179/207
108	156/166	195/217	163/169	94/106	246/254	179/195
109	148/152	195/233	159/163	94/106	246/254	179/207
110	148/152	217/227	153/169	92/94	252/254	179/195
111	156/166	195/233	159/163	94/106	246/248	179/207
112	148/152	227/233	153/159	92/94	246/248	179/207
113	148/152	----	153/169	92/94	246/254	179/195

114	156/166	195/217	163/169	94/106	248/252	179/207
115	152/166	227/233	153/159	92/94	252/254	179/207
116	----	195/233	----	----	246/254	----
117	148/156	227/233	153/159	92/94	246/254	179/207
118	148/152	195/217	163/169	94/106	246/248	179/207
119	----	217/227	153/169	92/94	248/252	179/207
120	152/166	227/233	153/159	92/94	248/252	179/195
121	----	----	----	----	----	----
122	----	195/233	----	94/106	246/254	179/207
123	148/156	195/233	159/163	94/106	252/254	179/207
124	----	227/233	----	92/94	248/252	179/207
125	152/166	195/233	159/163	94/106	252/254	179/195
126	148/152	217/227	153/169	92/94	252/254	179/195
<hr/>						
<u>Family 2</u>	<u>Soc 412</u>	<u>Soc 415</u>	<u>Soc 416</u>	<u>Soc 417</u>	<u>Soc 419</u>	<u>Soc 423</u>
Dam	128/148	193/225	161/163	86/92	246/254	179/201
Sire	126/134	191/191	163/165	86/92	246/252	183/193
1	126/128	191/193	161/165	86/92	246/254	179/193
2	126/128	191/193	161/165	86/86	246/254	193/201
3	134/148	191/193	161/165	86/92	252/254	179/193
4	126/148	191/225	163/163	86/92	252/254	183/201
5	134/148	191/225	163/165	86/86	246/246	193/201
6	134/148	191/225	163/165	86/86	246/254	----
7	128/134	191/193	161/163	92/92	252/254	179/193
8	128/134	191/225	163/165	86/86	252/254	179/193
9	126/128	191/193	161/165	86/92	252/254	183/201
10	134/148	191/193	161/165	86/92	246/246	179/193
11	----	----	----	----	----	----
12	128/134	191/225	163/163	86/92	252/254	183/201
13	126/128	191/225	163/163	86/92	----	183/201
14	126/148	191/193	161/165	86/92	246/252	193/201
15	134/148	191/225	163/165	86/86	246/246	183/201
16	126/148	191/225	163/163	86/92	246/254	179/183
17	134/148	191/193	161/163	92/92	246/254	193/201
18	128/134	191/193	161/165	86/92	252/254	179/193
19	128/134	191/193	161/163	92/92	246/254	179/183
20	128/134	191/225	163/165	86/86	246/252	179/193
21	134/148	191/225	163/163	86/92	252/254	183/201
22	134/148	191/193	161/165	86/92	252/254	193/201
23	126/128	191/225	163/165	86/86	246/254	183/201
24	126/148	191/225	163/165	86/86	----	179/183

25	126/128	191/193	161/163	92/92	246/246	179/183
26	134/148	191/193	161/165	86/92	246/252	183/201
27	126/128	----	161/163	92/92	----	183/201
28	128/134	191/225	163/165	86/86	246/252	179/183
29	128/134	191/225	163/165	86/86	246/252	179/193
30	126/148	191/225	163/165	86/86	246/246	183/201
31	126/128	191/193	161/163	92/92	246/254	193/201
32	134/148	191/225	163/165	86/86	246/254	179/183
33	128/134	191/193	161/163	92/92	252/254	179/193
34	128/134	191/225	163/165	86/86	246/252	179/183
35	126/148	191/225	163/163	86/92	246/252	179/183
36	134/148	191/225	163/163	86/92	246/252	193/201
37	134/148	191/193	161/163	92/92	252/254	183/201
38	134/148	191/225	163/163	86/92	246/254	179/183
39	126/148	191/193	161/165	86/92	246/254	193/201
40	126/128	191/225	163/165	86/92	252/254	183/201
41	126/128	191/225	163/163	86/92	252/254	183/201
42	134/148	191/193	161/165	86/92	246/254	183/201
43	126/128	191/225	163/163	86/92	246/246	193/201
44	126/128	191/193	161/165	86/92	252/254	179/193
45	128/134	191/225	163/165	86/86	246/252	183/201
46	128/134	191/225	163/165	86/86	252/254	183/201
47	134/148	191/225	163/165	86/86	246/246	193/201
48	128/134	191/225	163/165	86/86	246/254	179/183
49	126/128	191/225	163/163	86/92	246/254	179/183
50	128/134	191/193	161/163	92/92	246/254	193/201
51	126/148	191/193	161/165	86/92	246/252	179/183
52	128/134	191/193	161/163	92/92	252/254	193/201
53	126/148	191/193	161/165	86/92	246/254	179/183
54	128/134	191/225	163/165	86/86	246/254	179/193
55	126/148	191/225	163/163	86/92	246/254	179/183
56	128/134	191/225	163/163	86/92	246/252	183/201
57	126/148	191/225	163/165	86/86	246/246	179/193
58	128/134	191/193	161/163	92/92	246/254	183/201
59	128/134	191/225	163/163	86/92	252/254	193/201
60	126/128	191/225	163/165	86/86	246/252	179/193
61	128/134	191/225	163/163	86/92	246/246	179/193
62	134/148	191/225	163/165	86/86	246/254	179/193
63	128/134	191/225	163/165	86/86	252/254	193/201
64	126/148	191/225	163/163	86/92	246/254	179/183

65	126/148	191/225	163/163	86/92	246/252	179/193
66	128/134	191/225	163/163	86/92	246/252	193/201
67	126/148	191/225	163/163	86/92	246/252	179/183
68	128/134	191/225	163/163	86/92	252/254	183/201
69	128/134	191/225	163/165	86/86	246/246	179/183
70	134/148	191/225	163/163	86/92	246/246	179/183
71	134/148	191/225	163/165	86/86	252/254	183/201
72	126/128	191/193	161/165	86/92	246/254	179/183
73	128/134	191/225	163/163	86/92	246/254	179/193
74	126/128	191/193	161/165	86/92	252/254	179/193
75	126/128	191/225	163/163	86/92	246/252	183/201
76	126/128	191/225	163/163	86/92	246/252	183/201
77	128/134	191/193	161/165	86/92	252/254	179/193
78	134/148	191/225	163/163	86/92	252/254	179/193
79	128/134	191/193	161/163	92/92	252/254	179/183
80	134/148	191/193	161/163	92/92	252/254	179/193
81	126/148	191/225	163/165	86/86	252/254	193/201
82	128/134	191/225	163/163	86/92	246/252	179/193
83	128/134	191/193	161/163	92/92	246/252	183/201
84	128/134	191/225	163/165	86/86	252/254	193/201
85	128/134	191/193	161/163	92/92	246/252	183/201
86	128/134	191/225	163/165	86/86	246/254	179/193
87	128/134	191/225	163/165	86/86	246/252	179/193
88	134/148	191/193	161/163	92/92	246/246	179/183
89	134/148	191/225	163/165	86/86	246/252	179/183
90	128/148	191/225	163/165	86/86	246/246	193/201
91	126/128	191/225	163/163	86/92	246/254	183/201
92	126/148	191/225	163/165	86/86	252/254	183/201
93	128/134	191/193	161/165	86/92	246/246	179/193
94	126/148	191/225	163/163	86/92	246/254	183/201
95	134/147	191/193	161/165	86/92	246/254	179/193
96	126/148	191/193	161/163	92/92	246/252	179/183
97	128/134	191/225	163/165	86/86	252/254	179/193
98	134/148	191/225	161/165	86/92	246/252	193/201
99	134/148	191/225	161/165	86/92	246/254	183/201
100	128/134	191/193	163/163	86/92	246/254	179/193
101	126/148	191/193	161/165	86/92	246/254	183/201
102	126/148	191/225	161/165	86/92	246/252	193/201
103	128/134	191/193	161/163	92/92	246/246	179/183
104	128/134	191/193	163/163	86/92	246/246	179/193



105	128/134	191/193	163/163	86/92	246/246	193/201
106	134/148	191/225	161/163	92/92	252/254	179/183
107	134/148	191/225	161/163	92/92	252/254	179/183
108	134/148	191/193	163/165	86/86	246/252	193/201
109	126/148	191/193	163/163	86/92	246/254	193/201
110	128/134	191/225	163/165	86/86	246/252	179/193
111	126/128	191/225	161/165	86/92	246/252	179/193
112	134/148	191/225	163/165	86/86	246/252	193/201
113	134/148	191/193	163/163	86/92	246/252	179/183
114	126/128	191/225	163/163	86/92	246/252	179/193
115	128/134	191/225	163/163	86/92	246/246	193/201
116	126/148	191/225	163/163	86/92	252/254	183/201
117	128/134	191/225	161/165	86/92	246/246	179/183
118	126/128	191/225	161/165	86/92	246/254	179/193
119	126/128	191/193	161/165	86/92	246/252	183/201
120	126/128	191/193	161/163	92/92	246/252	183/201
121	126/128	191/193	163/165	86/86	246/252	193/201
122	126/148	191/193	163/163	86/92	252/254	193/201
123	134/148	191/193	161/165	86/92	246/252	179/183

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### APPENDIX 12e

Genotypes at 31 microsatellites for dam, sire, and offspring in each of two families used in testing Mendelian segregation and independent assortment

<b>Family 1</b>	<b>Soc 424</b>	<b>Soc 428</b>	<b>Soc 432</b>	<b>Soc 433</b>	<b>Soc 444</b>	<b>Soc 445</b>
Dam	205/233	194/196	102/110	90/98	161/161	142/151
Sire	205/221	216/216	110/112	90/90	161/161	134/151
1	----	194/216	102/110	90/98	161/161	142/151
2	----	196/216	110/112	90/90	161/161	151/151
3	205/221	194/216	110/110	90/90	161/161	152/151
4	205/217	196/216	110/112	90/90	161/161	153/151
5	205/233	196/216	110/110	90/90	161/161	134/151
6	205/217	196/216	102/112	90/98	161/161	151/151
7	----	194/216	102/112	90/98	161/161	151/151
8	----	196/216	110/110	90/90	161/161	134/151
9	205/233	194/216	110/110	90/90	161/161	134/151
10	205/233	196/216	102/112	90/98	161/161	134/142
11	205/233	196/216	102/110	90/98	161/161	134/142
12	205/221	194/216	110/110	90/90	161/161	151/151
13	221/233	196/216	110/110	90/90	161/161	142/151
14	205/221	196/216	102/110	90/98	161/161	134/142
15	205/233	196/216	110/112	90/90	161/161	134/142
16	205/233	196/216	102/112	90/98	161/161	142/151
17	205/205	194/216	102/112	90/98	161/161	151/151
18	205/221	194/216	110/110	90/90	161/161	134/142
19	205/233	196/216	110/112	90/90	161/161	142/151
20	205/221	196/216	102/112	90/98	161/161	151/151
21	205/205	194/216	110/112	90/90	161/161	151/151
22	221/233	194/216	102/110	90/98	161/161	142/151
23	----	----	----	----	----	----
24	205/205	194/216	110/110	90/90	161/161	134/142
25	205/233	196/216	110/110	90/90	161/161	134/151
26	221/233	196/216	110/112	90/90	161/161	134/151
27	221/233	196/216	102/112	90/98	161/161	134/142
28	205/205	194/216	110/110	90/90	161/161	134/142
29	205/233	196/216	110/112	90/90	161/161	134/142
30	205/233	196/216	102/110	90/98	161/161	151/151
31	205/221	194/216	102/110	90/98	161/161	134/142
32	205/233	194/216	102/112	90/98	161/161	142/151
33	221/233	196/216	110/112	90/90	161/161	134/151

34	205/221	196/216	102/112	90/98	161/161	142/151
35	205/221	196/216	102/112	90/98	161/161	151/151
36	221/233	196/216	110/112	90/90	161/161	151/151
37	205/205	196/216	102/110	90/98	161/161	151/151
38	205/233	196/216	102/110	90/98	161/161	142/151
39	221/233	194/216	110/110	90/90	161/161	134/151
40	205/205	194/216	110/112	90/90	161/161	151/151
41	205/233	196/216	102/112	90/98	161/161	134/142
42	205/233	194/216	102/112	90/98	161/161	134/151
43	205/233	194/216	102/112	90/98	161/161	134/142
44	205/221	194/216	110/110	90/90	161/161	134/151
45	205/205	196/216	102/110	90/98	161/161	134/151
46	221/233	194/216	102/112	90/98	161/161	142/151
47	205/233	196/216	102/110	90/98	161/161	142/151
48	205/233	194/216	102/112	90/98	161/161	142/151
49	----	196/216	110/112	90/90	161/161	142/151
50	205/233	194/216	102/112	90/98	161/161	142/151
51	221/233	196/216	110/110	90/90	161/161	134/142
52	205/233	194/216	102/110	90/98	161/161	142/151
53	205/205	196/216	110/110	90/90	161/161	142/151
54	205/233	196/216	110/110	90/90	161/161	134/142
55	205/233	194/216	110/112	90/90	161/161	151/151
56	----	194/216	110/110	90/90	161/161	134/151
57	205/233	194/216	102/112	90/98	161/161	142/151
58	205/233	194/216	110/110	90/90	161/161	134/142
59	205/205	194/216	110/110	----	----	142/151
60	221/233	194/216	102/110	90/98	161/161	134/151
61	205/221	194/216	102/112	90/98	161/161	142/151
62	205/205	196/216	110/112	90/90	161/161	134/142
63	205/233	194/216	102/110	90/98	161/161	142/151
64	205/233	194/216	110/112	90/90	161/161	134/142
65	205/233	196/216	102/112	90/98	161/161	134/142
66	205/205	196/216	102/112	90/98	161/161	134/151
67	205/205	196/216	110/112	90/90	161/161	134/151
68	221/233	196/216	102/110	90/98	161/161	142/151
69	205/221	194/216	102/112	90/98	161/161	151/151
70	205/205	194/216	102/112	90/98	161/161	134/142
71	221/233	194/216	102/110	90/98	161/161	142/151
72	221/233	196/216	102/112	90/98	161/161	134/151
73	221/233	196/216	110/112	90/90	161/161	134/151

74	205/221	194/216	102/110	90/98	161/161	142/151
75	205/205	196/216	110/110	90/90	161/161	134/142
76	205/233	196/216	110/110	90/90	161/161	151/151
77	205/233	196/216	102/110	90/90	161/161	151/151
78	221/233	196/216	110/110	90/90	161/161	151/151
79	221/233	194/216	102/110	90/98	161/161	151/151
80	205/221	196/216	102/112	90/98	161/161	142/151
81	205/205	194/216	102/112	90/98	161/161	134/151
82	221/233	196/216	110/112	90/90	161/161	134/142
83	221/233	194/216	110/112	90/90	161/161	142/151
84	205/233	196/216	110/112	90/90	161/161	134/142
85	205/205	196/216	102/110	90/98	161/161	134/142
86	205/221	196/216	110/112	90/90	161/161	134/142
87	221/233	196/216	102/110	90/98	161/161	142/151
88	221/233	194/216	110/110	90/90	161/161	142/151
89	----	194/216	102/112	90/98	161/161	142/151
90	205/233	196/216	102/112	90/98	161/161	134/142
91	205/233	194/216	110/110	90/90	161/161	----
92	205/228	200/204	98/106	88/98	161/161	134/142
93	205/221	194/216	102/112	90/98	161/161	142/151
94	205/205	196/216	102/112	90/98	161/161	142/151
95	221/233	196/216	102/110	90/98	161/161	151/151
96	221/233	194/216	110/112	90/90	161/161	134/151
97	221/233	194/216	102/110	90/98	161/161	134/142
98	221/233	194/216	102/112	90/98	161/161	134/142
99	205/221	194/216	110/112	90/90	161/161	134/142
100	205/233	196/216	110/112	90/90	161/161	134/151
101	205/205	194/216	110/112	90/90	161/161	142/151
102	221/233	194/216	102/112	90/98	161/161	134/142
103	----	194/216	110/112	90/90	161/161	----
104	205/233	194/216	102/112	90/98	161/161	151/151
105	205/233	194/216	110/110	90/90	161/161	151/151
106	205/233	194/216	102/112	90/98	161/161	134/151
107	201/205	194/216	102/112	90/98	161/161	134/151
108	201/205	194/216	110/110	90/90	161/161	134/142
109	205/221	194/216	102/110	90/98	161/161	134/151
110	221/233	194/216	102/110	90/98	161/161	134/142
111	205/221	194/216	102/110	90/98	161/161	134/151
112	205/221	194/216	102/112	90/98	161/161	134/142
113	205/221	194/216	----	90/90	161/161	142/151

114	221/233	196/216	102/110	90/98	161/161	151/151
115	221/233	196/216	102/110	90/98	161/161	134/151
116	205/221	194/216	110/112	90/90	161/161	----
117	201/205	196/216	110/112	90/90	161/161	134/151
118	205/221	196/216	110/112	90/90	161/161	142/151
119	205/221	194/216	102/110	90/98	161/161	134/142
120	205/233	196/216	102/112	90/98	161/161	134/142
121	205/221	186/188	102/110	90/90	161/161	----
122	205/221	194/216	102/112	90/98	161/161	151/151
123	221/233	194/216	110/110	90/90	161/161	151/151
124	221/233	194/216	102/110	90/98	161/161	134/151
125	201/205	196/216	102/110	90/98	161/161	134/151
126	205/221	194/216	102/110	90/98	161/161	134/151
<u>Family 2</u>	<u>Soc 424</u>	<u>Soc 428</u>	<u>Soc 432</u>	<u>Soc 433</u>	<u>Soc 444</u>	<u>Soc 445</u>
Dam	219/227	220/228	104/104	88/92	161/161	142/145
Sire	225/225	206/212	100/102	94/100	161/163	143/145
1	219/225	212/220	100/104	88/94	161/161	143/145
2	219/225	----	102/104	92/94	161/161	143/145
3	219/225	206/228	100/104	88/100	161/161	142/143
4	219/225	212/220	100/104	88/100	161/161	143/145
5	225/227	206/228	100/104	88/94	161/161	143/145
6	225/227	212/220	102/104	92/100	161/161	143/145
7	219/225	212/220	102/104	92/94	161/161	143/145
8	219/225	206/220	102/104	92/94	161/163	142/145
9	219/225	206/228	102/104	92/94	161/163	142/143
10	219/225	206/220	100/104	88/94	161/161	143/145
11	----	212/228	----	88/100	161/161	----
12	225/227	212/220	100/104	88/100	161/163	142/145
13	225/227	206/220	102/104	92/94	161/161	142/143
14	225/227	206/228	100/104	88/94	161/163	145/145
15	219/225	206/228	102/104	92/94	161/163	142/145
16	219/225	212/228	102/104	92/94	161/163	142/145
17	219/225	212/228	100/104	88/94	161/161	143/145
18	225/227	212/228	102/104	92/94	161/163	145/145
19	219/225	212/228	100/104	88/94	161/163	145/145
20	225/227	206/220	102/104	92/94	161/161	143/145
21	225/227	206/228	100/104	88/100	161/163	142/145
22	219/225	212/220	102/104	92/100	161/161	143/145
23	225/227	206/220	102/104	92/94	161/163	142/145
24	225/227	206/228	102/104	92/94	161/161	142/143

25	225/227	206/220	100/104	88/94	161/163	142/145
26	219/225	212/220	100/104	88/100	161/163	145/145
27	----	212/228	----	92/94	161/163	----
28	219/225	212/220	102/104	92/100	161/161	142/143
29	225/227	206/228	102/104	92/94	161/163	142/145
30	219/225	212/228	102/104	92/94	161/161	142/143
31	219/225	212/228	100/104	88/100	161/163	142/145
32	225/227	212/220	102/104	92/100	161/163	142/145
33	225/227	212/228	100/104	88/100	161/163	142/145
34	225/227	212/220	100/104	88/100	161/163	142/145
35	219/225	206/220	102/104	92/94	161/161	142/143
36	225/227	206/220	100/104	88/100	161/163	145/145
37	225/227	212/228	102/104	92/100	161/161	142/143
38	225/227	212/228	102/104	92/100	161/161	142/143
39	225/227	212/220	100/104	88/94	161/163	145/145
40	219/225	212/228	102/104	92/94	161/161	143/145
41	225/227	212/220	102/104	92/94	161/161	142/143
42	225/227	206/228	102/104	92/100	161/163	142/145
43	225/227	212/220	100/104	88/100	161/163	142/145
44	225/227	206/228	102/104	92/100	161/163	145/145
45	219/225	212/228	100/104	88/100	161/161	142/145
46	219/225	206/228	102/104	92/94	161/163	145/145
47	225/227	206/220	102/104	92/100	161/161	142/143
48	219/225	206/220	102/104	92/94	161/161	143/145
49	225/227	212/220	102/104	92/100	161/163	142/145
50	219/225	212/220	100/104	88/94	161/163	142/145
51	225/227	212/220	100/104	92/100	161/163	142/145
52	225/227	212/228	100/104	88/100	161/163	145/145
53	219/225	206/220	102/104	92/100	161/161	142/143
54	219/225	212/220	100/104	88/100	161/163	145/145
55	225/227	212/220	102/104	92/94	161/161	142/143
56	219/225	206/228	100/104	88/94	161/163	142/145
57	225/227	206/220	100/104	88/94	161/161	142/143
58	219/225	212/220	100/104	88/94	161/161	143/145
59	225/227	212/220	102/104	92/94	161/163	142/145
60	219/225	212/220	102/104	92/94	161/161	143/145
61	219/225	212/228	102/104	92/94	161/161	143/145
62	225/227	212/228	100/104	88/94	161/161	142/143
63	225/227	212/228	102/104	92/100	161/161	143/145
64	219/225	206/220	102/104	92/94	161/161	143/145

65	219/225	206/228	102/104	92/94	161/161	142/143
66	225/227	206/220	102/104	92/94	161/163	142/145
67	225/227	206/228	100/104	88/94	161/163	143/145
68	225/227	206/228	100/104	88/94	161/161	143/145
69	219/225	206/220	100/104	88/94	161/163	142/145
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72	219/225	212/220	102/104	92/100	161/161	142/143
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74	225/227	212/220	102/104	92/94	161/163	142/145
75	219/225	206/220	100/104	88/94	161/163	145/145
76	225/227	212/228	100/104	88/100	161/161	143/145
77	219/225	206/228	100/104	88/100	161/163	142/145
78	219/225	206/228	102/104	92/100	161/163	145/145
79	219/225	206/228	102/104	92/100	161/161	142/143
80	225/227	212/228	102/104	92/100	161/161	142/143
81	219/225	206/228	100/104	88/94	161/161	142/143
82	219/225	206/220	100/104	88/100	161/161	143/145
83	219/225	206/228	102/104	92/94	161/161	142/143
84	219/225	206/228	102/104	92/94	161/161	142/143
85	219/225	206/220	100/104	88/94	161/163	142/145
86	225/227	212/220	100/104	92/100	161/163	145/145
87	219/225	212/220	100/104	88/94	161/163	142/145
88	225/227	206/220	102/104	92/100	161/161	143/145
89	225/227	212/220	102/104	92/100	161/163	143/145
90	219/225	212/220	100/104	88/94	161/161	142/143
91	219/225	212/220	100/104	88/100	161/161	143/145
92	219/225	212/228	100/104	88/94	161/161	142/143
93	219/225	212/228	100/104	88/100	161/161	142/143
94	219/225	206/228	100/104	88/94	161/163	145/145
95	219/225	206/228	100/104	88/100	161/163	145/145
96	225/227	206/220	100/104	88/94	161/163	142/145
97	219/225	212/228	102/104	92/94	161/161	142/145
98	225/227	206/220	102/104	92/100	161/161	142/143
99	225/227	212/228	100/104	88/94	161/163	143/145
100	219/225	212/220	100/104	88/100	161/161	142/143
101	225/227	212/228	100/104	88/100	161/161	142/145
102	219/225	206/220	102/104	92/100	161/161	143/145
103	225/227	206/220	102/104	92/100	161/163	145/145
104	225/227	206/220	102/104	92/94	161/161	142/145

105	219/225	212/220	102/104	92/100	161/163	142/145
106	225/227	212/220	102/104	92/100	161/163	142/145
107	225/227	212/220	102/104	92/94	161/163	142/145
108	219/225	206/228	100/104	88/94	161/163	145/145
109	219/225	206/220	100/104	88/94	161/163	142/145
110	219/225	206/220	100/104	88/100	161/163	145/145
111	219/225	206/228	100/104	88/100	161/163	143/145
112	219/225	206/228	100/104	88/94	161/163	143/145
113	219/225	206/228	102/104	92/100	161/161	143/145
114	219/225	212/228	100/104	88/94	161/161	142/145
115	225/227	206/228	102/104	92/94	161/161	142/145
116	219/225	206/220	102/104	92/100	161/163	145/145
117	225/227	212/228	100/104	88/94	161/163	145/145
118	225/227	206/228	100/104	88/100	161/163	142/143
119	219/225	212/220	102/104	92/94	161/163	142/145
120	225/227	212/220	102/104	92/100	161/161	142/145
121	219/225	212/220	100/104	88/100	161/163	143/145
122	225/227	212/228	100/104	88/94	161/163	143/145
123	219/225	212/228	100/104	88/94	161/163	142/145

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